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RADIATION PROTECTION CRITERIA AND STANDARDS: THEIR BASIS AND USE

SUMMARY-ANALYSIS OF HEARINGS MAY 24, 25, 26, 31, JUNE 1, 2, AND 3, 1960

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OF THE

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RADIATION PROTECTION CRITERIA AND STANDARDS: THEIR BASIS AND USE

Summary-analysis of hearings held on May 24–26 and May 31–June 3, 1960

I. Introduction

During May and June 1960 the Special Subcommittee on Radiation of the Joint Committee on Atomic Energy held 7 days of public hearings on "Radiation Protection Criteria and Standards: Their Basis and Use." It was the intent of these hearings to emphasize concepts and understanding of subject matter from a broad point of view rather than the strictly technical aspects. These hearings were, therefore, something of a departure from the pattern of the 1957 and 1959 hearings and other hearings on related subjects in 1959.[1] The printed hearings, including the advance committee print,[2] will represent a contribution of importance to the literature on radiation protection, particularly in its broader social, economic, and policy aspects.

It was also the intent of the hearings to emphasize more heavily than in earlier hearings the organizational and administrative aspects of radiation protection in the Government. Of specific interest was the question of who develops radiation protection criteria and standards and for what purposes. Also of specific interest was the question of who adapts basic exposure dose recommendations for actual application in atomic energy activities, whether of the Government itself or under license or other control.

The earlier hearings mentioned above provided extensive background discussion of a wide range of related topics such as—

(1) Radiation protection standards and their historical development.

[1] "The Nature of Radioactive Fallout and Its Effects on Man," hearings before the Special Subcommittee on Radiation of the Joint Committee on Atomic Energy, Congress of the United States, 85th Cong., 1st sess., May 27, 28, 29, June 3, 4, 5, 6, and 7, 1957, 3 vols. plus summary-analysis.

"Fallout From Nuclear Weapons Tests," hearings before the Special Subcommittee on Radiation of the Joint Committee on Atomic Energy, Congress of the United States, 86th Cong., 1st sess., May 5, 6, 7, and 8, 1959, 4 vols. plus summary-analysis.

"Industrial Radioactive Waste Disposal," hearings before the Special Subcommittee on Radiation of the Joint Committee on Atomic Energy, Congress of the United States. 86th Cong., 1st sess., Jan. 28, 29, and 30, Feb. 2, and 3, 1959, 5 vols. plus summary-analysis.

"Employee Radiation Hazards and Workmen's Compensation," hearings before the Subcommittee on Research and Development of the Joint Committee on Atomic Energy, Congress of the United States, 86th Cong., 1st sess., Mar. 10, 11, 12, 17, 18, and 19, 1959, plus advance committee print, plus summary-analysis.

"Federal-State Relationships in the Atomic Energy Field," hearings before the Joint Committee on Atomic Energy, Congress of the United States, 86th Cong., 1st sess., May 19, 20, 21, 22, and Aug. 26, 1959, plus advance committee print.

"Biological and Environmental Effects of Nuclear War," hearings before the Special Subcommittee on Radiation of the Joint Committee on Atomic Energy, Congress of the United States, 86th Cong., 1st sess., June 22, 23, 24, 25, and 26, 1959, plus summary-analysis.

[2] "Selected Materials on Radiation Protection Criteria and Standards: Their Basis and Use," Washington, U.S. Government Printing Office, May 1960, 1,244 pp. (Note: This document is referred to as the "preprint" in the rest of this summary-analysis.)

(2) History of the National Committee on Radiation Protection and Measurements (NCRP), International Commission on Radiological Protection (ICRP), and International Commission on Radiological Units and Measurements (ICRU).

(3) Statements of the National Academy of Sciences, the United Nations Scientific Committee, and the United Kingdom Medical Research Council on radiation hazards.

(4) Summaries of current NCRP and ICRP recommendations on radiation protection limits.

(5) NCRP recommendations on regulations of radiation exposure by legislative means.

(6) Regulation of the uses of nuclear materials and facilities.

(7) Applications of workmen's compensation principles to radiation hazards.

(8) Experiences with radiation hazards in AEC and private installations.

(9) Standards in relation to radioactive waste disposal.

(10) Interests of Federal and State Governments and private groups in radiation hazards.

(11) Radiation protection standards applied to fallout problems.

The new hearings, therefore, were focused on radiation protection criteria and standards to provide a unified treatment of many points treated but fragmentarily before.

A panel of advisers [3] of qualified scientists and others concerned with radiation protection both inside and outside of the Government was set up to assist the subcommittee in preparing for the hearings. A detailed outline of the hearings was developed [4] and some 50 persons were invited to testify or submit material for the preprint.

The major purpose of the preprint was to bring together information, particularly from the Government agencies, for prospective witnesses to review before the hearings started.

Witnesses were asked to view the subject matter broadly. Their statements do not, therefore, readily form a sequential presentation of subject matter as for the 1957 fallout hearings, for example. A rough sequence of presentation was worked out according to the following main topics:

I. The nature of radiation protection standards and criteria (introductory information).
II. Activities of Federal, State, and private agencies in radiation protection, and relationships among agencies and groups concerned with radiation protection criteria and standards.
III. Concepts underlying radiation protection criteria and standards:
    A. Biological concepts
    B. Social and economic concepts and concepts of risk
    C. Concepts of practical application
IV. Organizational, administrative, and legislative relationships and problems.

As the hearings actually worked out, topic II provided information which was discussed throughout the later part of the hearings with a climax with topic IV.

[3] See list in preprint, p. iv.
[4] See preprint, p. x.

As in some of the earlier hearings mentioned, roundtables were used to help focus discussion.

Two important documents became available to the public shortly before the hearings started:

(1) The 1960 National Academy of Sciences report on "The Biological Effects of Atomic Radiation." [5]

(2) The May 11, 1960, memorandum for the President from the Federal Radiation Council [6] (FRC) along with a staff report.[7]

The issuance of the Federal Radiation Council memorandum and staff report effectively changed the emphasis of the hearings even further away from technical discussions to discussions on organization and on policy and on applications of the guidance set forth in the Council memorandum.

The purpose of this summary analysis is to put down in simple terms a statement of what the hearings were about. It does not cover all of the wealth of information available in the printed hearings or in the preprint. Preparing a summary analysis of necessity involves making value judgments as to what is to be summarized and thus emphasized. The reader should, after reading this summary analysis through, have some impression of where the country stands in the field of radiation protection criteria and standards, of what the hearings actually accomplished, and of what is left for the future.

The reader is encouraged to examine the full testimony in the printed hearings and the preliminary written statements in the preprint.

As before, the Special Subcommittee on Radiation owes much to the willing help of the many scientists who prepared material and otherwise helped these hearings to serve their purpose. To them, the thanks of the subcommittee.

II. Summary of Key Points

Some general observations may be made on the results of the hearings:

Radiation exposure doses in the United States

According to estimates presented in the record of the hearings, the total 30-year per capita radiation exposure dose to the gonads of persons in the United States is about 7 to 8 rem, about equally divided between natural background radiation and manmade radiation sources. The total 30-year per capita radiation exposure dose to the bone (osteocytes) of persons in the United States was estimated to be about 5 to 7 rem, about one-quarter of this being manmade and the rest natural background radiation. The total manmade radiation exposure to persons in this country is almost entirely (90 percent or more) that resulting from exposure of medical patients to X-rays, diagnostic and therapeutic.

[5] "The Biological Effects of Atomic Radiation," summary reports from a study by the National Academy of Sciences, Washington, 1960. (Excerpted in preprint, p. 1191.)

[6] "Radiation Protection Guidance for Federal Agencies," memorandum for the President prepared by the Federal Radiation Council, May 11, 1960. Signed by the President on May 13, 1960, and entered in the Federal Register on May 18, 1960 (F.R. Doc. 60-4539). (See appendix, p. 46.)

[7] "Background Material for the Development of Radiation Protection Standards," Report No. 1, staff report of the Federal Radiation Council, May 13, 1960. (See also hearings, p. 623.)

The need for radiation protection criteria and standards

Ultimately, the need for radiation protection criteria or standards arises from two facts:

(1) Development of the uses of atomic energy and other sources of ionizing radiation will inevitably be accompanied by the exposure of persons to manmade ionizing radiation.

(2) Enough is known about the biological effects on man of ionizing radiation to permit agreement on the following: For the present, the most reasonable working assumption for protection purposes is that all such exposures, however small, have an associated biological risk (that is, an associated degree of likelihood of harmful biological effect).

In some fields of atomic energy, such as the development of aerospace applications, important and urgent decisions relating to radiation protection face the country.

Experience in other fields

It would appear that the field of industrial hygiene, and those aspects of public health practice having to do with manmade threats to the general public health, are most likely to provide useful experience for application to radiation protection and the development of suitable criteria and standards. The subcommittee strongly recommends a greater degree of communication and cross-discussion of ideas in these fields.

Types and purpose of radiation protection criteria and standards

Witnesses brought out clearly the multiplicity of things meant by "radiation protection criteria and standards." This situation tends to make the record harder to understand, particularly when comparisons are made. Witnesses readily agreed on the general purposes of radiation protection criteria and standards. Only with difficulty did they agree that the basic NCRP and ICRP radiation dose and radium 226 body burden recommendations are meant as a basis for decisions and action in a somewhat limited field (peaceful uses of atomic energy). There is a need for more thinking leading to clear and well-formulated concepts as to what the various types of criteria and standards of radiation protection are for and how they are to be used.

Biological effects of radiation

Witnesses agreed that there is a large body of applicable knowledge of the biological effects of radiation on animals and man. The state of our knowledge of the biological effects of radiation compares very favorably with that of other hazards to health in this respect. Witnesses agreed, as stated above, that the best working assumption for protection purposes is one attaching some risk of harmful biological effect to every dose, no matter how low. This assumption is not unique for radiation.

Current opinion on the value for a maximum permissible dose for large populations tends to cluster around dose levels of one to two times natural background (to be added to the natural background itself).

Social and economic factors

Witnesses gave widely divergent viewpoints of how social and economic factors in the field of radiation protection should be con-

sidered in developing criteria and standards. There was similar divergence on whether or not social and economic factors had been taken into account in arriving at the basic dose recommendations of NCRP and ICRP.

The subcommittee considers it essential that a basis of agreement be established on the social, economic, and policy aspects of radiation protection because of the importance of the subject to the Nation and the public as a whole.

Practical application

Witnesses tended to be unsure of the scope of application for which either basic NCRP-ICRP dose recommendations or FRC radiation protection guides are meant. For example, there was contradictory testimony on whether NCRP recommendations apply to fallout. There is obviously a need for clarification of such points.

Witnesses gave almost no consideration to a point the subcommittee regards as highly important for the future: how are decisions to be made on introducing future major new sources of manmade radiation exposure and what happens when actual population exposure levels approach the limits of NCRP, ICRP, or FRC?

The Federal Radiation Council

The first memorandum issued by the Federal Radiation Council was considered highly significant by witnesses because it marks a major turning point in the Government's approach to problems and policies in the field of radiation protection. Witnesses, and the subcommittee, had considerable difficulty in understanding the scope and meaning of the FRC radiation protection guides as they might apply to actual practical situations.

Major unresolved questions concerning the Federal Radiation Council

Several major unresolved questions concerning the Federal Radiation Council arose:

(i) Will the President, with the advice and assistance of the FRC, make the basic value judgments and exercise final and direct responsibility for the setting of radiation protection standards, or will each Federal Agency perform this role in formulating its own standards and devising its own regulations?

(ii) What role will the FRC play in and how would the FRC meet the problem of ever-increasing manmade radiation exposure levels? Will a system of allocation (pie cutting) be followed or will each agency have the full limits (guides) for its own use?

(iii) How will the National Committee on Radiation Protection be affected in view of the role now being assumed by the FRC?

(iv) Do the activities of the FRC remove standards-setting functions from the application of usual administrative and procedural safeguards (such as the right of appeal) set forth by statute?

(v) Does the FRC provide for adequate representation of agency as well as public interests and for adequate representation of professional, including scientific, disciplines?

(vi) What staffing is appropriate for the performance of FRC functions? To what extent should FRC be primarily a policy

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group, emphasizing broad social and economic and policy factors, or to what extent should it be a group devoted to the technical details of standards setting?

(vii) What does "normal peacetime operations" as used in the Council memorandum mean?

Regulatory problems

A major unresolved question still exists as to how to keep the flexibility characteristic of such guidance as the FRC radiation protection guides and at the same time meet the need for legal precision in regulatory application.

III. Detailed Discussion of the Results

The need for radiation protection criteria and standards

In essence, the need for radiation protection criteria or standards was described by witnesses as arising ultimately from two basic facts:

(1) Development of the uses of atomic energy and other sources of ionizing radiation will inevitably be accompanied by the exposure of some persons to manmade ionizing radiation.

(2) Much is yet to be learned about the biological effects on man of ionizing radiation. Enough is known, however, to permit agreement that, for the present, the most reasonable working assumption for protection purposes is that all such exposures, however small, have an associated biological risk. That is, an associated degree of likelihood of harmful biological effect. This is true for many toxic materials as well and is not limited to radiation.

Thus the need for protection against radiation exposure—and, as will be made clear, for criteria and standards of radiation protection. An approach to an understanding of this need in terms of broad public or national policy was presented in the preprint statement of the U.S. Naval Radiological Defense Laboratory:

> One of the outstanding characteristics of civilization is the ability of man to divorce himself progressively from dependence on nature. In the process, the natural environment in which the human race has developed has been sharply modified. It is unthinkable that a modern civilization will allow such modifications to proceed unhindered and ungoverned. As a part of this greater picture, manmade sources of radiation are merely one class of things that contribute to the general alteration in our environment. We do, however, have practical experience to prove not only that radiation in large amounts is a lethal agent, but also to prove that smaller amounts have deleterious effects on the persons irradiated and on the future well-being of the race. There are limits to human tolerance for modification of the environment. Our modern civilization is quite capable of creating conditions exceeding these limits, and it is the purpose of radiological protection criteria to delineate the boundaries of unacceptable alterations of the environment.
>
> On the other hand, we cannot insist on zero alterations and zero risk in the development of a new industry which contributes immensely to man's well-being, wealth, and power over his environment. Some degree of biological effect is associated with any exposure to ionizing radiation, and this effect must be accepted as inevitable. Since we don't know that these effects can be completely recovered from, we have to fall back on an arbitrary decision about how much we will put up with; i.e., what is "acceptable" or "permissible"—not a scientific finding, but an administrative decision.

The Laboratory developed these ideas further and then, in the summary to its preprint statement, noted:

1. A statement of acceptable level of radiation-induced injury (or chance of injury) is the essential keystone to any national policy related to radiation protection. This statement must account separately for the level of acceptable injury to the race by genetic damage and the risk to the individual of somatic damage.

This determination is a problem of national policy in the highest sense of the word.

2. This limit of acceptable risk of injury to people becomes the standard against which all factors are judged. It is not a "standard" which is approached as closely as possible (e.g., a standard of weight). It is a condition (e.g., a cliff), which one stays as far away from as conditions permit. The closer one approaches the edge, the more careful he becomes.

3. Against this framework, the function of radiation protection criteria or standards of any kind is to guide the actions of people in relation to their environment. Their violation breaks the rule, but does not define when one has been pushed over the cliff.

4. The total acceptable quantity of radioactive materials in the environment requires strict attention to the annual quantities, their concentrations at any point, and the repetitiveness of the condition. Transient concentrations well above the equilibrium concentrations can be accepted for short periods. Concentrations of active materials above the "average" can be accepted in even food and water, provided their annual contribution to the diet is below the acceptable average. NRDL sees the management of radioactive materials in the environment as a dynamic process implementing national policy specifying the range of acceptable risks to the population. Standards and criteria should implement dynamic management over the full range of conditions, but for the common objective of keeping radiation exposures to people within the prescribed acceptable levels.

Thus it is that the Nation is presented with a basic decision. A particularly timely instance of the kind of decision we face has to do with current and planned future development of atomic energy for rockets and space vehicles (aerospace applications). The following excerpt from the preprint statement of Lt. Col. Joseph A. Connor, Jr., and Dr. Donald M. Ross presents the issue:

Consider the added measure of military security attendant with a manned nuclear-powered aircraft which will provide an airborne capability with a range limited only by the endurance of the men in the crew compartment. The possibility of thereby maintaining a major portion of the force on constant airborne alert would obviate the advantage of a surprise attack.

Consider the tremendously increased power possessed by nuclear rockets which will make feasible for the first time the orbiting of high-payload satellites and space stations.

Consider the war-deterrent advantage afforded by nuclear ramjet, low altitude, high-speed missiles freed by its unlimited range from the predictable trajectory, and capable of weaving, feinting, and dodging while seeking out selected targets.

Consider the expanded usefulness of satellites powered by nuclear reactors geared to provide kilowatts and even megawatts of power for months or years at a time.

These, then, are the horizons portended by the successful developments of aerospace nuclear propulsion. But each of these uses hold forth the possibility of injecting additional radioactivity into our atmosphere.

It is worth pausing at this point to remember that manmade radiation exposure is in addition to the existing natural background radiation exposure originating from cosmic rays and naturally occurring radioactive materials. The relative contribution of the various sources to man's total natural background radiation dose appears in the following table presented by Mr. H. M. Parker in testimony:

TABLE I.—*Estimated background radiations*

	Soft tissue dose, mrem/year	Bone dose, mrem/year	Lung dose, mrem/year
Cosmic rays:			
Sea level	30	30	30
5,000 feet	70	70	70
Total external gamma:			
Out-of-doors [1]	100	100	100
In buildings:			
Wood [2]	60- 65	60- 65	60- 65
Brick [2]	110-125	110-125	110-125
Concrete [2]	180-230	180-230	180-230
Internal emitters:			
Carbon-14	2	[3] 2	2
Potassium-40	20	[3] 9	20
Radium-226		[3] 40	
Radon			[4] 70-1,000
Thoron			[4] 50- 600

[1] This is taken as at sea level. The generally reported range is about 50 to 150 mrem per year. In a few areas it rises above 1 rem per year.
[2] Measurements in specific buildings in Sweden; apparently such differences are not usually not so pronounced.
[3] Osteocyte dose.
[4] Variations with building types and degree of ventilation.

To the natural background exposure, then, can be added estimated manmade exposures. The two put together give man's total estimated exposure to ionizing radiation, as in the following table also from Mr. Parker:

TABLE II.—*30-year per capita doses in the United States from radiation sources*

Source	30-year dose	
	Gonad dose rem	Bone dose [1] rem
Natural radiation:		
External:		
Cosmic rays	0.9	0.9
Terrestrial radiation	2.1	2.1
Atmospheric radiation	.06	.06
Internal:		
Potassium 40	.6	.3
Carbon 14	.06	.06
Radon-Thoron	.06	.06
Radium		1.2
Subtotal	~3.8	~4.7
Manmade radiation:		
Diagnostic X-ray	[2] 3	1.4
X-ray therapy	.36	[3]
Internal isotopes	<.03	[3]
Luminous dials	.03	[3]
Television	<.03	<.03
Atomic energy workers	.003	.003
Medical workers	.03	[3]
Subtotal	~3.5	~1.4
Approximate total	7-8	5-7

[1] Taken here as the osteocyte dose to match table I. This principally affects the radium entry which would be 0.05 rem for mean marrow dose.
[2] Additional studies on limited groups have given values on the order of 1.5 rem.
[3] No estimate.

The manmade sources of radiation exposure given in table II can be classified into three main parts:

(1) Medical exposures, diagnostic and therapeutic, to the patient.

(2) Exposure to those occupationally associated with radiation sources, including those medically employed.

(3) Exposures to large or small segments of the general public, owing to the existence of manmade radiation sources in the environment at large.

These categories suggest, among other things, two basic problems of radiation protection, to which much testimony was devoted:

(1) The decision to undergo radiation exposure can be individual in nature, as for patients undergoing medical treatment, or social in nature, as for the release of radioactive materials to the environment. How is the decision to be made?

(2) The degree of radiation exposure can be altered by—

(*a*) controlling radiation sources;

(*b*) controlling people;

(*c*) controlling the environment such as alleviating environmental contamination already existing.

How is adequate control to be had?

It is evident that a need for some sort of generalized guidance in the form of *criteria* or *standards* for radiation protection, or even more basically, for *policies* of radiation protection exists.[8] Two further considerations remove doubt:

(1) The likely uses of atomic energy are widespread and varied. It is not to be expected that each user can develop on his own an adequate approach to protection.

(2) Radiation protection requirements can be expected to have a significant effect on the uses of atomic energy.

The nature of standards

Distinct notions of what is meant by "standards" have grown up over the years in such fields as science, engineering, and law. Standards may be voluntary or enforced, refer to something to be lived up to or something to be avoided, recommendatory or binding, guiding or specific. Health protection standards in particular may be designed (i) to control the actions of persons potentially exposed to some threat, (ii) to control the actions of persons in a position to expose others to some threat, or (iii) only to provide information to someone who must add other information before coming to an action.

In his introductory testimony, Mr. H. M. Parker summarized the essential characteristics of standards in general and as applied to radiation protection as follows:

> In summary, standards are—
>
> (1) Models for judgment as to whether a given action should be taken;
>
> (2) Communications of the expert to guide those less experienced;
>
> (3) Crystallizations of past experience utilized to facilitate future actions;
>
> (4) Means for integrating a whole made up of many parts.
>
> Particularly in technological fields, well-conceived standards fulfill these purposes: They promote safety, promote simplification, encourage further improvements, contribute to orderly development of the technology.
>
> Of the several ways in which standards may originate and develop, two seem to be of particular relevance in the radiation protection field. The first concerns

[8] The words in italic can here be understood in their dictionary senses as more or less special meanings of the general term rule. The more specific meanings directly related to the subject of radiation protection are discussed in this summary-analysis.

moral and ethical standards of which the Hippocratic oath, defining the standard of conduct of a physician with respect to a patient, is a sound example. In application to radiation protection, concern for the well-being of our future generations in the face of the deleterious genetic effect of ionizing radiation must lead to standards of this kind.

A standard of the second type can be called an action facilitator, a device to allow each individual in society to proceed in a certain direction, confident that certain obstacles have been removed. The rule of the road is a simple example. In just this sense there is a class of radiation protection standards designed to permit an individual to proceed with reasonable safety for himself and with the assurance of not causing unreasonable interference with the needs or work of others.

Dr. Francis J. Weber provided a comprehensive review of the historical background underlying the establishment of standards. The review appears in the preprint; excerpts from the summary and conclusions follow:

Throughout recorded history, the matter of standardization has proved a leading concern in virtually all institutions of organized societies. The rulers of nations, and officials working under their direction, have participated actively in the establishment and enforcement of standards of various types. This has included the overseeing of standardization based on scientific measurements and procedures where the standards proved to be of general applicability in public affairs.

National leaders, during the early history of the United States, followed in this tradition by encouraging the development of standards for weights and measures. John Quincy Adams stated that standards should be characterized by uniformity, permanency, and universality.

From its very simple beginnings, several thousand years ago, the field of standards has broadened to one of considerable complexity. It has resulted in the need for pursuing an intricate process of standardization similar to that of any other specialty. This process now involves the establishment of standards of a type by which the extent, quality, value, performance and service of any important activity may be judged.

Standards in the various scientific fields share with those of other endeavors a common origin represented by the early attempts to establish weights and other simple measures. With progress in the discovery of natural laws, the types of standards which necessitated by such discoveries have increased greatly in number and complexity. All, however, are found to depend upon three fundamental measurements: length, mass, and time, with the other units derived from them.

The fields of medicine and public health utilize some of the more complex standards. This complexity is brought about by the need to coordinate scientific knowledge and practices based upon it, with the value systems of various group of the society which these disciplines serve. Standards in these fields developed a little later in the history of modern science than they did in other sciences like physics.

The first modern health standards to appear were probably those developed from the progress made in the correct categorization of diseases. Through this application of the scientific method, a reproducibility of diagnostic results was thereby rendered possible. With an increase in the understanding of the role of environmental vehicles of disease transmission, plus contributions in the field of therapy, reproducible results revolving around the applications of useful standards help make possible the significant conquest of the communicable diseases.

The health disciplines have been able to progress in other areas as well. Health and safety standards, designed to provide a proper base of operations for noncommunicable disease hazards in the environment, like those issuing in fatal accidents and injuries, have also been evolved to a high degree, followed in many cases by striking results.

The scientific community, which began with national efforts, gradually extended itself to the international area. By virtue of this common concern with effective standards, there has now evolved a large and varied body of universal standards for the better management of health problems of man.

However, many difficult and complex areas remain in the health field, in part due to the special relationships and intimate connections with activities in other fields operating within the general fabric of society.

* * * * * * *

Modern science, in creating new ways of looking at the universe in which man finds himself, has only added to the problems of standardization, a matter, which until lately, was a more easily conducted process. For one thing, it has enlarged the hiatus between modern scientific understanding and that of the general public. As a result of this, as well as other factors, standardization in certain fields continues in an unsettled state.

Lessons from other fields of health protection

For the hearings the subcommittee stressed the desirability of approaching the subject of radiation protection criteria and standards from the standpoint of the extensive background on health and accident protection standards in general. The field that seems to offer the best possibilities for analogy is industrial hygiene and related public health practice. There, too, the threat to health (industrial chemicals, smokes, etc.) are man made, and—as for manmade radiation—can be controlled in several ways as mentioned above.

Dr. Abel Wolman discussed the lessons that might be learned from other fields of health protection. Excerpts from his testimony follow:

A rough classification of the procedures often used is as follows:
(*a*) Regularizing techniques of measurement * * *
(*b*) Establishing limits of concentration or density of biological life, physical and chemical constituents, etc. * * *
(*c*) Regularizing administrative practice.
(*d*) Regularizing legislative fiat.
(*e*) Specifying materials (which does not concern us here). * * *

As one moves from (*a*) through (*d*), the universe becomes not only more complex, but more nebulous. The hope that an authoritative rule may be substituted for thought and judgment is an ever present desire of some administrators, of the quantitative-minded precisionist, of the lawyer and always the distressed citizen. All are beleaguered by the multiplicity of problems. To resolve these by formula has always been the will-of-the-wisp hope of workers in every field of human application.

* * * * * * *

The general field of public health practice should historically disclose precedents, philosophy, implications, and examples.

* * * * * * *

(*a*) The development of criteria for the protection of health has invariably preceded full scientific understanding and acceptance. * * * The criteria have been eternally subject to reinterpretation, adjustment and reframing, as newer knowledge and experience were forthcoming. Sometimes such revisions have been overdue, even though the machinery for revaluation, both voluntary and official, was at hand.

* * * * * * *

(*b*) The development of standard techniques of measurement has had full value, even though this standardization also tends to stultify scientific advance. When the advantages are weighed against the chaos of dissimilar techniques of measurement, which preceded standard methods, the balance is undoubtedly on the side of a common language.

* * * * * * *

(*c*) Criteria to guide administrative practice have been used with caution in the public health field. Appraisal sheets, coupled with assessments of current practice, have had variable results even when issued by voluntary groups. The fear of freezing practice, paralleled by the desire to facilitate intelligent administration, have been the characteristics of such excursions. The appraisal sheets have provided aids to improved coverage in public health and have not proven too resistant to new knowledge. Again relative success with standardizing practice is due in great part to the concomitant provision of machinery for continuing revision of the bases for appraisal.

(*d*) How has the health worker balanced criteria against risk to life? The past record of public health accomplishment, of which one has reason to be eminently proud, is singularly devoid of such quantitative evaluations. * * * The fact that the American public lives in one of the highest protected public health

environments in the world is not contested. That this is the result of the composite of public health measures, standard of living, genetic influences and other factors is likewise true.

But the saving of lives and the extension of life have been the result of public health practices to a significant degree. It must be recognized, however, that the guiding principle that public health is purchasable was a qualitative philosophical precept, rarely a quantitative equating of protective criteria against loss of man or dollars. Efforts at the latter equation have not been rare, but quite unimpressive in general impact either upon the people or their legislators. * * * They are rarely interested * * * with the effort of measuring the economic value of the newborn babe, but the Western acceptance of the general obligation of society to prevent disease and death is the prevailing one.

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It is only with the search for criteria for radiation limits that one finds suggestions that it should be permissible to kill people to attain benefits to society. This has undoubtedly been in the minds of all criteria makers, but rarely has it reached the frank and stark pronouncements of recent years.

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(g) Were the results of continually higher standards for health protection unduly costly in dollars? It is rare to have encountered public or private agencies in the past which did not plead poverty and excessive costs of corrective.

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Fear has been expressed that the establishment of too rigid criteria for the radiation activity may stifle progress because of excessive costs of attainment. One may view this fear with some cynicism in the light of the whole history of health and safety endeavor. This fear has always been expressed, but the historical reality consistently belies it. Criteria must rest upon public health protection and not cost.

A somewhat contrary view was provided in the preprint statement of Mr. William Harris, discussing how the industrial hygienist sees health protection:

* * * when the responsibility of an individual engaged in health protection is defined, one discovers a dual responsibility. First, to insure that the health and/or well-being of the individual in no way be impaired, while at the same time insuring that the operation continues. If the first specification is impossible without discontinuing the operation and removing it from the industrial scene, then of course this is the action which must be taken. However, it is the fundamental responsibility of the health protection engineer to discover means by which the operation may be safely carried on, while at the same time insure that it can be done economically. This is the great value, and at the same time the tremendous responsibility, of the health protection engineer. Making an operation safer and ever safer is easy; making it safe and economical is the problem.

Purposes and types of radiation protection criteria and standards

For the field of radiation protection itself, many witnesses of course addressed themselves to the question of what standards and criteria are for. To understand the testimony, and the later parts of the summary-analysis, one must keep in mind that the terms radiation protection criteria or standards were used, sometimes without explicit definition, to mean any of the following things:

1. Publications by the National Committee on Radiation Protection and Measurements (NCRP). These include (i) the basic exposure dose recommendations (Handbook 59 and revisions [9]), or—for bone seekers—radium 226 body burden recommendations, (ii) derived recommendations of concentrations of radioactive materials in the environment (Handbook 69), and (iii) a number of handbooks on specialized topics such as radiation protection for X-ray machines and for handling radium. Also included in NCRP publications is Handbook 61, dealing with legislative codes for radiation protection.

[9] These revisions appear officially as addenda.

The basic dose and radium 226 body burden recommendations are intended primarily for occupational use. Recommendations derived from these occupational values are applied to persons living in the vicinity of radiation controlled areas. An ad hoc committee established by the NCRP published the recent report on somatic exposure to large populations.[10]

2. Publications by the International Commission on Radiological Protection. These include recommendations generally compatible with those of the NCRP and have been published as supplements to the journal Radiology or in Health Physics or by Pergamon Press. The ICRP has, however, included in its recent report [11] recommendations or suggestions for somatic and genetic exposure to large populations.

3. AEC manual chapter 0524, adapting directly NCRP recommendations (basic and derived) for use in AEC contract operations.

4. Regulations (10 CFR 20) published by AEC in the Federal Register for application to individuals and organizations holding AEC licenses. These are also adaptations of NCRP recommendations, but with some variation.

5. The memorandum of May 11, 1960, from the Federal Radiation Council to the President. This was approved by the President for the guidance of Federal agencies and published in the Federal Register. Radiation exposure guides, which correspond roughly to the basic dose recommendations of the NCRP and ICRP, are given for Federal agencies to use as a basis for establishing their own regulations for radiation protection.[12]

6. Regulations established by individual States and municipalities. These regulations vary considerably with respect to the sources of radiation exposure included and the extent to which the regulations make specific requirements. Some State and local governmental bodies have regulations covering X-ray machines and natural radioactive elements such as radium; others have few or no laws for radiation protection. Although the extent of State regulatory activity varies rather widely among the various States, such radiation protection levels as do exist in State codes are generally consistent with recommendations of the NCRP:

7. American Standards Association (ASA). The ASA has been concerned with standards in such nuclear energy fields as uranium mining and milling, nuclear fuel fabrication, and others.

8. Working standards of atomic energy plants. These are often some percentage of basic and derived NCRP or ICRP recommended levels.

Such a multiplicity of meanings naturally leads to some difficulty in understanding the testimony and the written statements in the preprint. A subtle, but important, example is the tendency to compare different sets of standards without full explanation of the meaning of the comparison. This is particularly confusing when some may be said to be "numerically the same as" others.

The hearings focused primarily on NCRP and ICRP basic dose and radium 226 body burden recommendations, and on Federal

[10] Somatic radiation dose for the general population, Science, Feb. 19, 1960, v. 131, No. 3399, pp. 482–486. (See also Preprint, p. 1085.)

[11] Recommendations of the International Commission on Radiological Protection (adopted Sept. 9, 1958). Pergamon Press, London, 1959. (Excerpted in preprint, p. 1121.)

[12] The apparent inconsistency here with the preceding item is only transitory; AEC will in the future base 10 CFR 20 on guidance from the Federal Radiation Council, according to testimony given.

Radiation Council radiation protection guides, rather than on the derived and adapted forms of these standards.

The U.S. Naval Radiological Defense Laboratory considered at length in its preprint statement the purpose of basic dose recommendations and guides:

NRDL perceives that the policies and standards for radiation protection have to serve two purposes: (*a*) preservation of the health of employees and the public at large; (*b*) preservation of the opportunities for economic and social advancement that present a uniquely promising future for this Nation. The demands of preparedness to resist aggression may often make the two purposes competitive. In such cases, decision cannot rest on medical and nuclear science alone, but must involve value judgments. Standards should therefore be equipped with administratively acceptable means for their relaxation in necessary circumstances * * *. The standards should be firm enough to protect the population from inadvertent risks to personal health and the genetic future.

* * * * * * *

The function of MPD and MPC is to provide a guide for safe conduct under conditions which could be quite dangerous. Radiation protection standards do not define the danger; rather, they define the path by which the danger can be avoided. To lift them from their proper context compromises all the general and special rules of conduct on which their use depends.

* * * * * * *

The MPC's which define limits of radioactive materials in various parts of the industrial environment are in effect the basis of the inspection system by which the performance of the nuclear installation is judged. To this extent, their use is quite comparable to the visual inspection made by the building inspector of an electrical installation in a building or home.

* * * * * * *

These are specific examples of classes of standards, one of which is designed to hold down the magnitude of a potential threat, while the other is designed to live successfully in spite of the presence of a threat. Using a simple analogy, the MPC's recommended by the NCRP have the characteristics of building codes whereas the working standards as used by NRDL and AFSWC have the attribute of providing the judgment of whether or not your hand is dry enough to pull the cord on an electrical fixture. The two are related, but are far from identical.

In the same statement, the Laboratory noted further the requirements placed upon radiation protection criteria and standards by the differing characteristics of the sources of radiation exposure which must be considered:

The distinguishing characteristics of the various major sources of the radiation exposure to be considered in these hearings are related to the degree to which the quality and characteristics of the radiation exposure condition can be related to the source, and is known. Consider the practical problems of dealing with protection from an X-ray machine. The radiation characteristics are known. The machine is in a known position, and is highly controllable. The problem here is quite different from that created by radioactive isotopes in the environment. The location, quantities, and potentialities for exposure from these isotopes are far more difficult to identify. However, even in the case of environmental radioactivity, the sources differ in respect to the quantities, types of isotopes, identifiability and specification of location. Thus a weapon test gives a massive production of radioactive materials, the disposition of which can be technically identified in general terms, but can, by no means, be controlled to the degree that the discharge of radioactive waste from an atomic energy site can be controlled.

Dr. Robert Newell's preprint statement brings out the decision- and action-relatedness of radiation protection criteria and standards:

The field of our attention is properly called radiation hygiene. The means is radiation protection. This has to be guided by a policy, and the accomplishment measured against criteria.

* * * * * * *

The eligible policy is up for decision, which, being necessarily arbitrary, and now seen to affect, potentially, the lives of all of us, is a political decision and properly debatable. It is in fact being widely and warmly debated. It is important to see that such decisions are not scientific conclusions. Their purpose is to mold the future, not merely to predict it. One foot should of course be planted on scientific knowledge, and the more firmly the better. But the other stands on human ideals and sentiments. This is what gives so much heat and color to the debate. And this is where a lively skepticism is properly applicable to any person's testimony, be he scientist or humanist, to distinguish what is observational and logical and intended to inform, from what is oratory and intended to persuade.

* * * * * * *

In view of the above evidence that scientists know very little indeed about the effect of total body exposures of the order of 5 r, what do the NCRP and ICRP think they are doing when they promulgate 5 r per year as the criterion for radiation protection? Obviously they are not building a fence along the edge of the chasm of disaster. In fact the NCRP writes, "permissible dose [is] * * * not expected to cause appreciable bodily injury to a person at any time during his lifetime."

It is now agreed that MPD is an arbitrary limit (like a speed limit on the highway) designed to limit the probability of injury.

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For ordinary industrial hazards, we estimate the present hazard and judge how well we are doing in accident protection by counting the accidents as they occur. Unobservable injuries don't count.

By contrast, for radiation hazard we don't wait for the injuries to appear. We estimate the hazard by measuring the radiation. Instead of judging our policy and program for accident prevention by the observed frequency of injuries, we take the observed frequency of the several levels of radiation exposure. When dealing with the future read not "frequency" but "probability."

The biological effects of radiation

In keeping with the planned scope and purpose of these hearings, the subject of the biological effects of radiation as such was not a major part of the hearings. This subject was discussed in considerable detail in the 1957 fallout hearings, with further discussion in the 1959 fallout hearings to bring matters up to date. The progress of research could not be expected to provide dramatic changes in our understanding over such short time periods. This view was essentially borne out by the 1960 report of the National Academy of Sciences on the biological effects of atomic radiation, already mentioned, and by testimony.

In contrast, what was meant to be an important part of the hearings was the question of how, by what approach, our existing knowledge of the biological effects of radiation has been adapted to the development of radiation protection criteria and standards, particularly the basic dose recommendations and guides. From the testimony it would appear that, for both the NCRP basic dose recommendations and the FRC radiation protection guides, the approach to using our knowledge is based on substantial scientific agreement as to the present state of knowledge and the nature of its limitations.

State of knowledge on biological effects of radiation

As suggested by Dr. G. Failla [13] in his testimony, our information on the biological effects of ionizing radiation is by no means nil. Reviews have been published by—

(i) the National Academy of Sciences in 1956 and 1960;
(ii) the United Kingdom Medical Research Council in 1956;
(iii) the United Nations Scientific Committee in 1958;
(iv) the NCRP;

[13] See appendix p. 55, and p. 66, for excerpts from the preprint statements of Dr. G. Failla and Dr. R. Evans and Dr. R. Dudley on the historic basis of the NCRP basic dose and radium 226 body burden recommendations.

(v) the ICRP; and

(vi) more briefly, by the Federal Radiation Council which has used consultants extensively.

Furthermore, it appears that NCRP and the Federal Radiation Council have taken notice of the reviews made by other groups in arriving at assessments of biological effects.

Dr. Austin Brues' preprint statement discusses the state of our knowledge by making comparisons with knowledge in related fields:

A very important fact that we tend to forget is that we know a great deal more about radiation than about any other occupational or environmental hazard leading to late or occasional bad results, such as cancer. Take, for example, benzpyrene. This is a chemical substance which was shown by Hieger and Kennaway in the early 1930's to be a powerful agent for producing cancer in mice. It is produced in fairly large quantities (in terms of its cancer-producing potency) in the combustion of petroleum, can be measured in the air of our large cities, and settles on our window sills in easily measurable amounts. Yet no experimental work has been done with this substance, attempting to evaluate its hazard in low doses which compares with the admittedly inadequate work that has been done in trying to evaluate radioactive strontium and several other radio elements. The records show that we have given chronic treatment with strontium 90 alone in our own laboratory, to 5 or 10 times as many dogs as have been treated with benzpyrene in the whole history of chemical cancer research. Investigators of radiation have a very good idea of radiation effects on the cell; of the action of benzpyrene and its chemical cousins on the cell we have almost no knowledge at all.

We may quite properly ask ourselves whether radiation is something so radically different in its action from other noxious agents that we must use different criteria in evaluating it. Quite frankly we don't know, and the chief reason why we don't know, is our lack of the same detailed information about other hazards—chemical and dietary hazards in particular—which we have about radiation.

Approach to developing basic dose recommendations and radiation protection guides

In the 1957 and 1959 fallout hearings, a central point of interest was the question of whether or not a "threshold" for biological effects exists, that is, whether or not there is a radiation dose for which, and below which, there are no biological effects. Another, related question was what the shape of the radiation dose-biological response curve might be, in particular, whether it might be a straight line. The new hearings did not add to the earlier information, but witnesses did emphasize the need for clarity when using such concepts as "threshold" and "linear dose-effect." Dr. Austin Brues' preprint statement on this point is excerpted below:

I would like to look a little more deeply into the matter of the use of certain popular words in connection with radiation injury, including injury by radioactive elements such as strontium 90. The first is the word "threshold." This word has always implied to me that a certain amount of damage is definitely and completely recoverable. A second is the word "linearity" which implies that each amount of radiation produces a directly proportional hazard of some damage—be it cancer, leukemia, or life shortening.

The idea has been popularized that one or the other of these conditions has to exist. To me, it is essentially a foolish and unscientific procedure to choose the first two hypothetical guesses that come to mind, and to set them off against each other. Unfortunately this is the way a great many people have been trained to think; they find it very difficult to encompass more than one conflict of concept at a time. Even many scientists find it convenient to test one theory at a time. This is all right provided it is used as a guide for further theory; it is fallacious when it is done for the sake of decision making.

Actually, there may be no "threshold" for chronic radiation effects in the true sense, and yet the true picture may conform very closely to it. I have implied this in previous testimony and publications. Quite lately, Dr. Burch of Leeds, England, has come up with a definite, third hypothesis, backed up by data on leukemia and cancer and by basic scientific considerations, yielding a "two-hit"

theory. While this theory, like the others, is still a little too simple for my likes, it would suggest that the number of leukemias produced by small amounts of radiation may be real but extremely small. I think that our concepts would be a little more realistic if we were to drop the word "threshold" altogether when it is a word that is used as the alternative to the "linearity" hypothesis.

The following points summarize the testimony as to the import of our knowledge from the standpoint of formulating basic dose recommendations and radiation protection guides:

(1) We have enough indirect information from data on human beings, supported by extensive data from experimental animals, to judge with some confidence what the upper limit to the hazard to an individual exposed to radiation doses in the neighborhood of 5 rem per year might be. Much more information is needed.

(2) For radioactive materials seeking the skeleton, much of the human data is not in terms of radiation dose-effect but rather in terms of radium–226 body-burden-effect; otherwise the situation is as for (1).

(3) In the very low dose range, below where sufficient data exist, biological effect—in the absence of confirming evidence one way or the other—should be assumed as occurring with some degree of likelihood, but not certainty, at all doses, no matter how low. That is, one does not assume the existence of a threshold dose below which no effect occurs. This assumption does not state completely the relationship between effect and dose. It might be a straight line (linear) relationship or it might not. Furthermore, this assumption does not, when applied to somatic effects, state what particular effect (or, in more technical language, what particular biological end-point) may occur all the way down to zero dose. The assumption is rather that at least one such effect will so occur.

(4) For both genetic and somatic effects, whatever effect may occur must, on net balance, be considered harmful. Obviously, this assumption is not purely a biological one, depending as it does upon some notion of "harm."

(5) In the absence of sufficient data in the low-dose range, the fact of mankind's historical existence in an environment of natural background radiation can, at least to some extent, be a priori substituted for data on the grounds that this experience is not totally irrelevant but tends to set an upper limit to the harm that radiation can cause at dose levels approximating that of the natural background.

To capture the spirit of the adaptation of biological information to the development of the basic dose recommendations of NCRP and ICRP as accurately as possible (and similarly for the FRC guides, as discussed in the staff report of the FRC), a portion of Mr. H. M. Parker's preprint statement is reproduced in the appendix (p. 49). The quotation also gives a feeling for the extent, reliability, and usefulness of the human radiation exposure data available. The reader is further referred to the detailed preprint statements of Dr. G. Failla and Dr. Robley Evans, parts of which also appear in the appendix (p. 55).

The testimony indicated that present NCRP and ICRP basic dose recommendations and the FRC radiation protection guides are in keeping with the points given above and that the assumptions above fit our experience better than different ones.

Witnesses discussing the background of NCRP–ICRP basic dose and radium 226 body burden recommendations for occupational exposure tended to agree that the biological criterion used was that the recommended dose level be below a level known to have produced harmful effects in the persons exposed. The criterion for population exposure, whether individual-by-individual or on-the-average, was that the recommended dose level should be lower than that for occupational exposure by some numerical factor accounting for such things as increased heterogeneity and accumulated exposure before age 18.

It was noted by several witnesses, however, that the recommended dose levels for the population arrived at as described above do not differ meaningfully from levels that would be arrived at by taking directly some arbitrary small multiple of the natural background dose level. This latter approach has been recommended by some persons, including in these hearings Dr. J. Schubert and Dr. E. B. Lewis. Their statements appear in the preprint. The agreement of the two approaches was set forth by Dr. J. Crow in his testimony:

> * * * For the genetic dose the National Academy of Sciences committee recommended that the population average of manmade radiation from all sources be kept below 10 roentgens in a 30-year period. This is about three times the background level but includes medical and dental radiation. The NCRP recommendation is similar. The ICRP has recommended 5 rems for 30 years, plus the lowest possible contribution from medical exposure. The Federal Radiation Council has adopted this same value for its radiation protection guide.
>
> With respect to the somatic dose, the ICRP has suggested that for planning purposes the average concentration of such isotopes or mixtures thereof in air or water applicable to the population at large should not exceed one-thirtieth of the occupational values. For whole body radiation this is 1.70 millirems per year, or about 1.7 times the background level.
>
> The ad hoc committee recommended that the maximum permissible dose of manmade radiation, excluding medical and dental sources, should not be substantially higher than the background without a careful examination of the reasons for higher values. They suggested that the background level be arbitrarily taken to be one-tenth rem, or 100 millirem per year. The Federal Radiation Council recommends 170 millirem per year for whole body average for population groups. Thus there is a considerable agreement among all these groups. The various recommendations are of course not completely independent, for each group had previous reports of the other groups and several persons served in more than one group. But that all these groups agree that the natural background level is an appropriate yardstick and that the population average level should be in the range of 1 to 2 times background is significant.

Risk versus injury

Witnesses urged appreciation of the distinction between "injury" and "risk" and between "effect" and "incidence" for proper interpretation of the basic dose recommendations and protection guides. These terms will be dealt with next:

(1) A person whose skin is locally irradiated with high radiation doses (for instance, a single dose of several thousand r in a short time) who subsequently shows skin burns is clearly injured. A person receiving a much lower dose may show tissue changes. He also would by some persons be said to be injured in the sense of changed though not necessarily in the sense of impaired; here, effect would be better than injury.

(2) A group of persons (a population) may be irradiated with a dose in the range of 100 r or less. If some criterion of injury is adopted, say leukemia or bone tumors, one may attempt to observe whether or not more persons in the group had leukemia than would have if the irradiation had not occurred. The incidence of leukemia thus

may have been increased by the radiation but, since everyone in the group was irradiated, everyone in the group was put at an increased risk of suffering leukemia or bone tumors. Note, however, that the population was at some risk anyway, because these injuries occur naturally.

(3) For a given dose, and where a threshold does not exist, the *larger* the population irradiated the *more certain* it is that the incidence of some injury such as leukemia will be increased. Thus, with increasing population size, the risk that one or more members of the population group will receive some injury such as leukemia approaches a certainty that such an injury will occur in one or more members of the population group. In the very low dose region it is properly the risk, or likelihood of genetic or somatic injury, that is assumed to increase with dose, as discussed earlier.

Other points of clarification on biological effects

Another term whose meaning as used varies is "safety factor." This may refer to (*a*) a presumed degree of safety achieved by setting basic occupational dose levels (recommendations) at some percentage of the lowest dose level that has produced observable effects, (*b*) the presumed additional degree of safety achieved by setting exposure dose levels for the population at a lower value than occupational, or (*c*) the presumed additional degree of safety achieved by operating plants who set their working levels, whether for occupational or population exposure, at a lower value than the basic NCRP-ICRP recommendations. For all of these uses, it is to be kept in mind that the term "safety factor" may be somewhat misleading in view of the dictum "keep exposures as low as possible" based on the assumption that all doses, however low, can be associated with some biological risk.

On one rather technical point, witnesses provided a clarification long overdue. This has to do with the meaning of a so-called negative experiment or other series of observations in which a certain biological effect has not been observed. What conclusions can be drawn? Not automatically that the effect doesn't occur at the radiation doses used. Not, furthermore, that such a dose is inherently safe. A proper interpretation of such an experiment requires, among other things, technical steps to establish whether the effect could be observed under the conditions of the experiment even if the effect were known to occur at the doses used. At most, an upper limit is set on the effect to be expected from the doses used. This upper limit may, however, be many times larger than the true incidence. Such experiments do not confirm biological thresholds for dose-effect relationships. Thus, some witnesses pointed out that exposure at the recommended dose levels of NCRP or ICRP for occupational conditions, or even at the lower levels for populations, do imply biological risk even though effects at such dose levels have never been observed. In short, "no effect observed" is not equivalent to "a threshold exists" and the basic dose recommendations of NCRP or ICRP, or the FRC guides are not to be thought of as "safe" if by "safe" is meant zero biological risk. These points are developed in the preprint statement of Dr. J. Schubert, including an illustration.

Further information on biological effects in the record

The subcommittee was interested in why the basic NCRP–ICRP dose recommendations have been successively lowered over the years.

Both testimony and preprint statements deal with this point, and there is not complete agreement even though this is somewhat a matter of history. Disagreement is to be expected on matters arrived at by committees but explained by individuals, especially when time has passed by. See statements of Dr. Failla, Mr. H. M. Parker,[14] Mr. W. Harris, Dr. R. Morgan, and Dr. J. Schubert.

For the record, the subcommittee received—and wishes to express appreciation for—three technical statements on (i) the development of NCRP–ICRP recommendations of maximum permissible concentrations, (ii) internal dosimetry, both by Dr. K. Z. Morgan, and (iii) uncertainties in the NCRP–ICRP maximum permissible concentrations, by Dr. Walter S. Snyder. Dr. Snyder's statement also considers in detail the "supplementary questions on boneseekers" included in the subcommittee's outline.

The discussion of the social and economic basis of radiation protection

The subcommittee hoped that the discussion of the social and economic basis of radiation protection criteria and standards would bring out at least broad agreement on an approach to the subject even if the approach could not be carried very far for lack of information. It was, of course, recognized that the nature of the subject is such as to leave the way open for witnesses to make of it much as they might wish.

The hearings clearly brought out, however, that the hoped for agreement was premature. It was not that answers were unavailable. Often they were available and from several witnesses. But the answers were by and large piecemeal. Only occasionally was a reasonably comprehensive discussion of the broad subject matter available from one witness. By hindsight, this result might have been expected. For example, suppose there were biological data available showing definitely what the radiation dose-biological effect relationship in man really is. How, as one witness (quoted below) suggested, would one even then proceed to set standards or guides for the many activities involving radiation exposure?

It is likely that the reader also will have difficulty in viewing radiation protection as a social and economic problem, though it is important to have some appreciation of this viewpoint to understand the results of the hearings. To this end, excerpts from the testimony of Dr. Forrest Western and Mr. Jack Healy appear below. These pose the issues that the subcommittee was interested in.

(Dr. Western's testimony:)

> Because it is almost always possible to effect some further reduction in the exposure incident to a particular activity with sufficient additional effort, the only way in which we can defend any level of exposure is on the basis that the reduction of the exposure to any lower level would not be worth the effort required. As one progressively reduces the exposure to radiation from any source, he finds further reduction increasingly difficult to accomplish. Whether the effort is measured directly in the cost of more elaborate facilities or in terms of inconvenience, loss of time, or actual abandonment of a desirable activity, the effect is the same. In fact, most of these are ultimately evaluated in terms of dollars.
>
> There are many ways of expressing this concept. For brevity, let us say that we should not accept the risk associated with any exposure to radiation unless the reasons for accepting the exposure outweigh the risk.
>
> This concept represents a difficult hurdle in our effort to formulate meaningful standards of radiation protection. In fact, one might reason that this principle

[14] See appendix for excerpts from Dr. Failla's (p. 55) and Mr. Parker's (p. 49) preprint statements.

excludes the possibility of establishing general limits of radiation exposure which are meaningful.

How, for example, could a group such as the NCRP or the FRC, no matter how well informed they may be, determine that some level of exposure such as 0.5 rem per year is the breakpoint at which one cannot increase the radiation exposure of any individual member of the general population without the resulting biological hazard becoming more important than the reasons for accepting the hazard?

Even if we had filled in all of those gaps in our knowledge of the biological effects of radiation to which we frequently refer, we could not make a detailed analysis of the reasons for permitting various persons to be exposed to various manmade sources of radiation.[15] And, if we could, the highest justifiable exposure found in the general population would be applicable only to the person for whom it was determined.

Obviously, we cannot accept a conclusion that there is no way of arriving at radiation protection guides of some value. Our problem, then, is to find the best possible compromise between these conflicting considerations in order that we may develop the most appropriate guides possible.

At best the problem is very complex. I am sure that we could not obtain agreement among the persons here on the purpose of the guides. Are we, for example, trying to establish the limits of exposure which the general population is willing to accept, or are we trying to establish limits of exposure which the population should be willing to accept?

Obviously the first objective could be inadequate and we have no criteria for the second.

Perhaps we are seeking to determine to what extent the population might be willing to accept the hazards of exposure to radiation if all the members were reasonably well informed on the nature and degree of the hazard and on the advantages to be gained from the activities which give rise to the exposure.

In any event, we know that there is a need for appropriate criteria of radiation protection and we must provide the best which can be devised. I am aware that there are differences of opinion on how problems of this kind may best be solved and, in fact, on the manner in which the solution to this particular problem has been brought to its present stage.

In discussions of the subject which have been held in these hearings, I believe there is one important factor that has sometimes been underestimated. This is the interplay between various persons and groups of persons interested in the subject of radiation protection.

(Mr. Healy's testimony:)

Discussions of the financial aspects lead rapidly into my final point since the monetary values are of real importance only as they bear on the balance between safety and progress in the use of radiation and atomic energy. There is, today, a real desire to provide safe working conditions for employees and to avoid possibly hazardous conditions to the public. In most cases, this desire involves applying the recommendations or standards derived by those best qualified in the field. We can, therefore, expect that the accepted exposure limits will be applied regardless of cost. If, however, the cost becomes so great that the work cannot be carried out with the funds available, then the work will not be done.

The risk principle can be applied in this problem. Presumably the decision has been made that we will use radiation and atomic energy. This cannot be done without exposing some people to radiation. In other words, if we assume a nonthreshold type of response, we cannot employ these processes without exposing some people to a risk. In so doing, we would like to strike a balance in which the maximum benefits are obtained through use of radiation with the minimum harm. Our problem, then, arises since we cannot accurately define the risk nor can we accurately define the benefits to all people. Even if we could define these factors, there would still be controversy as to the proper level at which the balance should be taken since each appraiser applies somewhat different experience and background in his judgment.

Ultimately our problem resolves itself into the broad area of overall social risk and progress. Are we warranted in setting limits at such a level that any individual has an increased risk? Should we differentiate between the individual who benefits directly from the applications and the member of the population at large who benefits only indirectly? How do we strike a proper balance between the interests of the individual and the interests of the Nation? How do we bal-

[15] Italics supplied by committee.

ance our efforts to protect from radiation with the effort to eliminate other sources of injury? These questions should be emphasized as illustrative of the compromises which must be reached if we admit that uses of radiation and radio active materials are worthwhile.

The many points of view on balancing benefit and risk

The reader, to understand the testimony on benefit and risk, should keep in mind that witnesses tended to disagree more in the earlier parts of the hearings than later on, partly because of efforts in questioning and otherwise to bring out more specifically and clearly the individual points of view. But at one time or another, witnesses tended to disagree, first, on whether a balancing of benefit and risk is an appropriate procedure at all, and second, whether or not this procedure has been followed by NCRP, ICRP, and the Federal Radiation Council. Nowhere else in the hearings can so much directly contradictory testimony (or preprint statement) be found. Contradictions such as the following appear in the record:

(NCRP:)

(1) NCRP basic dose recommendations were developed considering only the biological (dose effect) factors and are as such purely scientific assessments of risk requiring that social and economic judgments be applied before any decision or action is arrived at.

(2) NCRP basic dose recommendations were developed with social and economic judgments already built in and are, therefore, intended as a direct basis of decision and action.

(FRC:)

(1) The FRC radiation protection guides are based on social and economic judgments.

(2) The FRC took no formal or scientific approach to the social and economic problems involved. Consideration of these problems was limited to the review by the member agencies of drafts of the memorandum later approved by the President.

(3) The temporary staff preparing the Council memorandum and staff Report No. 1 included no one known to specialize in these areas.

[The staff report itself discusses possible approaches to social and economic problems involved but gives no discussion of the approach actually used.]

(NCRP-FRC:)

(1) FRC radiation protection guides are similar to basic NCRP dose recommendations.[18]

With this background, the reader will appreciate the further detail that follows. On the desirability of making value judgments relating risk and benefit, the following excerpts from the record illustrate the divergent viewpoints:

(Mr. Staat's testimony:)

Basic radiation protection standards or guidance are quite unlike ordinary measurement standards. It is widely recognized that their formulation is not solely a matter of scientific determinations. As stated in the recent memorandum for the President from the Federal Radiation Council: "Fundamentally, setting basic radiation protection standards involves passing judgment on the extent of the possible health hazard society is willing to accept in order to realize the known benefits of radiation. It involves inevitably a balancing between total health protection, which might require foregoing any activities increasing exposure to radiation, and the vigorous promotion of the use of radiation and atomic energy in order to achieve optimum benefits."

(Dr. Wolman's testimony:)

The day of handbook rule for measuring the hazard of radiation is a long way off. In the meantime, one acts upon limited knowledge. In such action, the

[18] Contradictory in the light of the differences cited immediately above.

guiding principle must be the maximum protection of people, not because of sentiment, but because society demands it. An agreed acceptance of a number of consequent disabilities is not an appealing basis for the development, say, of nuclear power. Industry will do better than rest upon such an affront to man.

(Mr. Harris' statement in preprint:)

I believe that the public understands an economic balance. If so, wherever possible, the economic costs of protection should be balanced against the economic benefits of use to the world at large. This appears to be most possible by direct comparison with other types of hazards and with the amount of economic benefit and economic risk that each presents. Possibly in this way we can derive adequate standards for protection against radioactivity.

Historically, protection against hazardous materials is based not on a fear of damage but rather on the economic cost when damage occurs. Industry is constrained from injuring employees and the public not from a humanitarian viewpoint, but rather by the insurance cost that will accrue in the event of disaster.

Dr. Charles R. Williams provided background for this discussion by referring to the degree of attention that this subject [attempted balance of safe levels against the benefits derived therefrom] has received by standards-setting groups:

I have been involved in standards work for some 20 to 25 years in the occupational health field, and I must confess that rarely, if ever, have I heard such matters discussed in standards meetings. Basically, I believe it is the attempt of people who set the standards to assess all data that are available, and perhaps unconsciously consider questions of balance. But I don't believe that the standards people have faced this issue any more than it has been faced in these hearings to date.

That this question is far from theoretical in nature was illustrated by Dr. Russell Morgan in this testimony discussing the Department of Health, Education, and Welfare National Advisory Committee on Radiation's consideration of Sr^{90} levels in milk last year.

Part of the difficulty arises from the different meanings attached to ordinary words. For example, for some witnesses the term "scientific" did not include economics or social science. Sometimes the distinction was in reverse: A witness would advocate that the setting of basic dose recommendations must include social and economic value judgments but that there was no need or place for an economist or social scientist to help formulate the decision problem and judgments.

As another example, witnesses contended that cost did not properly have a place in the setting of basic dose recommendations but that some dosage must be accepted if there is to be activity in the field of atomic energy.

The reader will perhaps be assisted in untangling the language of the record by noting the following as usages of apparently simple words:

(1) "Cost" is used to mean such different things as (*a*) an actual or planned expenditure of money, for example, to reduce risk by increasing the degree of protection, (*b*) a benefit (of atomic energy) foregone, (*c*) the risk borne by a person or persons undergoing exposure to ionizing radiation.

(2) "Acceptable" is used to mean such different things as (*a*) a conscious decision, perhaps based upon some balancing of good and bad or progress and risk, (*b*) a decision implying a comparison, possibly subjective, with hazards from other causes, these latter being "acceptable" in turn in one of the senses given here, or perhaps just historically and possibly unconsciously, (*c*) the passive but substantive fact that nothing has been done to eliminate or curtail the thing being deemed "acceptable."

(3) A "balancing" of good and bad, benefit and risk, progress and hazard, may mean a conscious assessment of the factors involved, presupposing a decision, with the assessment (*a*) explicit and quantitative, or (*b*) implicit and qualitative, or the term may simply be (*c*) an inference conventionally believed to follow logically from the observed fact that a decision has been made.

Benefit and risk in development of basic NCRP-ICRP recommendations and Federal Radiation Council guides

With respect to economic and social concepts, and concepts of risk, the following would appear to be a consensus of the testimony, keeping in mind the previously mentioned difficulties with language:

(1) The essentially ethical-social judgment that "no cost is too high to pay for safety," sometimes expressed by saying that cost is irrelevant to the protection of persons from ionizing radiation, is agreed to in principle by most witnesses provided (i) "cost" is interpreted to mean direct expenditures of money—as for research, environmental monitoring, extra shielding, etc., and (ii) the judgment is qualified by a further recognition of the imperfect technology available now but of the opportunities for protection in the future.

(2) In a more fundamental sense, the hypothesis that all manmade radiation carries risk, plus the fact that development of atomic energy uses certainly will result in some persons becoming exposed to radiation, implies that (i) implicitly or explicitly, some sort of balance of progress and risk (including the cost of protection in the balance) is necessary, and (ii) that a decision to proceed, or not to proceed, with the uses of atomic energy automatically implies such a balancing, whether or not conscious.

(3) As a practical matter, it is nearly impossible to reduce to quantitative terms (put a dollar value on) the direct costs of radiation protection, partly because it is often difficult or impossible to decide that part of the total cost of an atomic energy plant or device which should be attributed to radiation protection.

(4) It is even more difficult to put into quantitative terms the cost equivalent to any radiation exposure risk borne by persons in lieu of protection, or to the benefits to be associated with any enterprise for which radiation protection may be required.

(5) Nevertheless, the NCRP has attempted to include economic and social considerations in its formulation of basic radiation protection dose recommendations, mostly by asking the question "can such and such an industry 'live' with a proposed dose level";[17] but this has been done only for peaceful uses, with specific testimony to the point that NCRP has not considered basic issues of national policy such as posed by fallout. (NOTE.—There is other contradictory testimony, however, stating that fallout is included.)

(6) The Federal Radiation Council also has attempted to include social and economic judgments in developing their radiation protection guides[17a]; this has been done by the already mentioned device of submitting the proposed guides to the Federal agencies involved,

[17] See Dr. Failla's testimony on this point in the record of hearings. Mr. Healy's testimony brought out the fact that NCRP habitually receives and considers views regarding the experience in applying their basic dose recommendations.

[17a] This is not to imply that the FRC has, or should have, gone about this in the same way that NCRP has. The testimony suggests that value judgments in NCRP recommendations were made on, and within the limits of, the authority of knowledge of its scientific-professional membership. The FRC, on the other hand, presumably has used a broader basis, extending outside the province of scientists, for arriving at value judgments underlying their guides. See also p. 39 for discussion of the related question of the need for the disciplines of social science and economics to partake in FRC work.

presumably again for a qualitative judgment. But this applies only for "normal peacetime operations," a term which was not defined, even on questioning.[18]

(7) Neither NCRP nor FRC appear to have given explicit consideration, for the atomic energy uses covered by their recommendations or guides, to the types of decisions actually to be made, although the consensus of testimony is that some decisions would certainly be determined by the recommendations and guides. For example, do FRC guides contemplate destroying food supplies at some point of rising environmental contamination levels?

Direct costs of radiation protection

The subcommittee especially wished to include in the preprint extensive background on the actual costs of radiation protection. That very little information actually exists in this field is brought out by Dr. G. Failla in the preprint by way of making a suggestion for further study which the subcommittee fully endorses:

> I should like to make another suggestion. The cost of radiation protection (e.g., in atomic energy plants) will play a more important part in the future than it has done in the past. It would be extremely useful to know: (1) What the cost is in different categories in order to comply with presently accepted permissible limits; (2) what percentage increase in such costs there would be if permissible limits were lowered by factors of 2, 4, and 8. To do this well it may be necessary to spend a large sum of money, but I think it would be well worthwhile. In fact I do not see how future considerations of permissible limits can be fruitful without such information.

The testimony, and especially the preprint, contains some valuable information (mostly applicable to large atomic energy plants) concerning the relationship between the degree of radiation protection provided and the direct (dollar) cost of providing it.[19] The following factors stand out:

(1) None of this information contemplates absolute protection. Radioactive materials will be released into the environment. Occupational exposures will occur regularly. Accidents will occur.

(2) How much money any additional protection would cost, or how much money could be saved by reducing protection requirements, depends sharply upon whether one is talking about plants and equipment which do not yet exist or about altering existing facilities.

(3) It the latter, the savings available by reducing protection requirements would appear to be small, although not zero. Operating costs could be reduced in some instances, but very little of the fixed costs could be recovered. On the other hand, increased protection requirements could mean greatly increased fixed costs—because of plant alteration or new plant construction—and increased operating costs.

(4) For new designs, reduced protection requirements might enable substantial savings, and increased protection requirements might be met without prohibitive expenditures.

(5) There are, however, real and firm limitations that are not readily attacked by revising designs and increasing expenditures of money. A primary example is the requirement of an exclusion area.

The difference between the conclusions of items (3) and (4) above lies primarily in the difference in opportunity for reoptimizing the

[18] See this Summary-Analysis, p. 32.

[19] The committee would particularly direct the reader to the Atomic Energy Commission statement pt. II and appendixes, and to the statement by Dr. Chauncey Starr, both in the preprint.

entire facility or plant. Optimization studies (sometimes called alternative design or economic balance studies) are common engineering practice, although evidently little has been done in relation to radiation protection.

The committee asked Mr. J. W. Healy to discuss this subject. His statement appears in the preprint.

Need for unification of concept

With respect to the social and economic concepts underlying radiation protection criteria and standards, the committee notes an apparent need for further development and unification of concept at the very foundation of radiation protection standards formulation. If the need is not satisfied, the greatest danger is not that individuals or populations will be unnecessarily subjected to radiation exposure—at least not in the near future—but rather the danger is that the developing military and commercial applications of atomic energy will continue to occur in an atmosphere of unnecessary governmental, commercial, and public tension and confusion as to what is actually being done for protection against radiation hazards. It would seem that the Joint Committee itself, the Federal Radiation Council, the agencies such as the Atomic Energy Commission and the Department of Health, Education, and Welfare, and to some extent such groups as the NCRP, the National Academy of Sciences, and other private groups, can contribute to means of satisfying this need. But there will be no substitute for competent scientific thought and careful judgment in such fields as biology, medicine, radiology, physics, social science, statistics, and economics.

Practical application of radiation protection criteria and standards

In activities involving the use of radioactive materials or the use of devices producing ionizing radiation, individuals and organizations face the specific, concrete problem of protecting persons, employees and the public at large, from the health hazard associated with radiation exposure. The normal approach to this problem is to use some sort of working standard of radiation protection. The hearings have, as already mentioned, brought out the fact of a multiplicity of committees, groups, and governmental organizations addressing themselves to the subject of standards and of the multiplicity of standards themselves.

If one is going to develop working protection standards from some set of recommendations or guides by one of the protection groups, a first step of necessity is to consider the rationale, the scope, and the intent behind whatever is to be used as a starting point. For example, as mentioned earlier, witnesses were not agreed on the extent to which basic dose recommendations or guides relate directly to contemplated decisions or actions. If they have a close relationship, then what actions in what fields? Some of the testimony was not qualified as to the field of activity to which it applied: For instance, sometimes occupational exposure, sometimes environmental contamination from industrial uses, sometimes fallout. Some of the testimony suggested that every type of decision, from (i) whether or not to resume weapons tests, to (ii) levels of waste disposal to the environment, to (iii) conditions for possible destruction of contaminated foods (in peacetime) all could be made on the basis of the same table of numbers

(dose recommendations), although it was not specified how such a universal table could be drawn up.

Some of the problems of using NCRP-ICRP basic and derived recommendations in practical situations were set forth by Mr. J. W. Healy in his preprint statement:

> Any standard which is used for control must be interpreted in terms of the conditions under which it is to be applied. In the application of such a limit much depends upon whether the standard is interpreted as a guide to be used in judgment in design and operation or whether the limit is to be used as an absolute limit with enforcement if the conditions exceed those specified. Present basic limits for radiation protection specify the radiation dose which should be received by certain critical organs. In general one can measure relatively small quantities of radiation and, of more importance, one can put devices on a person to measure his individual exposure. This permits a running record of the reading on the device. This reading, however, must be interpreted in terms of the radiation dose to the critical organ before the recommendations now available can be applied. Since the readings on such individual devices are widely used to show compliance with standards or legal codes, such standards are presently being interpreted as though they state that the device being utilized for measurement should not read greater than a given amount.
>
> It is possible that an individual exposed to exactly the maximum permissible limits, as indicated by the measurement, may actually receive doses to the critical organ system somewhat less than or somewhat greater than the permissible limit. If the recommendations are to be used as guides in providing protection, this discrepancy is not serious since the maximum permissible limits are a somewhat arbitrary balance of various factors and uncertainties and slight uncertainties in recording the exposure are insignificant. If, however, the limits are mandatory, the standards must be stated as measurements on a given instrument, standard conversion factors must be given, or the operating limits must be lowered to a point where it is improbable that any individual exceeds the limit even with the uncertainty in measurement.
>
> In the case of internal emitters, the primary limitations are the radiation dose to a given organ or, in the case of bone seekers, the energy release from the radionuclide as compared to the energy release from radium. The maximum permissible concentrations in air and water are derived by further utilization of biological data. In particular cases, the use of the maximum permissible concentration to control the quantity of radioactive material to which people are exposed can be overly restrictive or nonrestrictive. For example, the MPC for a material which has a long effective time of residence in the body is calculated on the basis that an individual will be exposed to the material over a period of time comparable to a lifetime. At the end of this time, the quantity in the body will have increased to that amount which will give the maximum permissible radiation dose. Thus, a momentary exposure to a concentration somewhat greater than that listed as the maximum permissible concentration is really unimportant in terms of the basic limitations on radiation dose. In this case, the MPC's are primarily intended to provide criteria to be used in designing a facility and indicating to the operator that some action is required.
>
> The MPC's are frequently used to designate the limits for air and water in the environs, usually with a reduction factor to allow for considerations involved in exposing populations. In these cases, many radionuclides can be concentrated to a marked degree by biological or physical processes. Such processes can result in concentrations in foodstuffs such that only a relatively small quantity of the food need be ingested to equal that amount which would be taken in if the full day's drinking water were obtained from the source. In these cases, then, the MPC's are not adequate to guide the actions of people carrying out waste disposal operations. From these standpoints, the standards labeled as "maximum permissible concentration," would be more appropriately labeled as "control concentrations" since they are intended primarily to indicate the need for action rather than to indicate that quantities slightly above this will produce a dangerous situation.

With respect to applying the Federal Radiation Council guides to practical situations involving population exposures, a problem of great

interest to the subcommittee and to the public, Dr. Forrest Western testified:

> At the present time, we are led to think of environmental standards in terms of limits on the exposure which might be received by any individual in a population group.
>
> This concept, which is automatically carried over from our occupational standards by the application of a numerical factor, is a very valid one but in the environmental situation is not a very useful one. This is because we are unable to avoid variation in environmental conditions, because it is generally impracticable and even undesirable to monitor the radiation dose received by each person in a population group, and because we may have little knowledge of or control over the activities of the individual.
>
> Aside from the fact that this is the way we are accustomed to expressing radiation protection criteria, why should we attempt to express environmental hazards in terms of the maximum dose which any person might conceivably receive? Our real objective is to limit the risk to the individual.
>
> The nature of the risk in which we are really interested is the very small probability that the exposure of the individual to environmental sources of radiation may result in a serious disease or genetic effect.
>
> In the end we can only restrict the environmental risk by restricting the activities that result in adding sources of radiation to the environment. In a specific environmental situation, there will result a more or less characteristic distribution of exposures to people in the environment. The overall risk to any one person depends not only upon the radiation dose which he might conceivably receive but also upon the probability that he will receive such a dose.
>
> The desirable objective in writing environmental criteria is to find meaningful and useful ways of limiting the risk in terms of the characteristics of the environment rather than in terms of the maximum dose to any individual in the environment. To the person who objects that he cannot accept any environmental condition in which there is even a small probability that some person might receive an exposure of 1 or 2 or 3 rems in a year's time, one can only ask, "How can one accept a certain exposure of 0.1 rem or 0.01 rem or 0.001 rem if there is a small probability that such an exposure will result in such a serious biological effect as, for example, leukemia?"
>
> It may be observed that the Federal Radiation Council has made some progress in developing this concept but has not put the concept in a clearcut form. As I understand the recommendation of the FRC it amounts to saying (1) that individuals in the general population should not receive radiation doses higher than 0.5 rem per year and (2) it may be assumed that this condition will be met if the environment is such that the average dose to persons living in the environment does not exceed one-third of this level, 0.17 rem per year * * *.
>
> It would be just as effective in terms of controlling the risk if one were to say that the risk to any individual living in the environment will not be considered excessive if the environment contains distributed sources of radiation resulting in an average exposure to persons in the environment not greater than 0.17 rem per year * * *.
>
> With the statement in the form given by the Council, past experience indicates that we will be plagued with the misgivings of many persons who realize that one cannot assure that in an environmental condition an individual exposure may not exceed three times the average and who fail to understand that the assumption is only a crutch by which persons accustomed to thinking in terms of limits applied to individuals make the transition to the more practical and useful concept of environmental control.

There does appear to be a general consensus on the following points with respect to applying the basic and derived NCRP and ICRP recommendations in practical operations:

(1) Application is for normal peaceful uses, meaning primarily such activities as power reactors, isotope uses, AEC production plants, waste disposal, etc., but not for special military uses such as weapons testing [20] and not for medical exposures to patients. If FRC guides also do not apply to radioactive contamination from weapons testing

[20] As previously noted, there is contradictory testimony on this point; see Dr. G. Failla's and Dr. K. Z. Morgan's preprint statements.

(worldwide fallout), then no authoritative recommendations of radiation exposure levels from such materials exist.

(2) In general, one tries to keep actual exposures as low as practicable, keeping well within NCRP–ICRP occupational exposure and environmental recommendations which, according to testimony given, is no undue technological burden.

(3) Exposures in excess of the recommended limits cannot be considered necessarily harmful.

(4) The recommendations are under rather constant review by the NCRP–ICRP, which include individuals able to speak for the practical problems of applying the recommendations.

(5) The ICRP–NCRP recommendations, while intended for use as decision-action standards, are by no means of self-applying but require professional judgment for practical application.

Practical application in particular fields of activity

The record, particularly the preprint, devotes many hundred pages to one or more aspects of the practical application of radiation protection criteria and standards to specific situations. The Atomic Energy Commission statement in the preprint gives comprehensive information for its major plants. Dr. R. Morgan, as already mentioned, discussed problems of Sr^{90} in milk. In the sections below, testimony on practical application for a few instances of particular interest to the subcommittee and the public are discussed briefly. The main value of the discussion to the general reader will be a bringing of concreteness and realism to one's view of the subject.

Radiation protection criteria and standards in relation to medical X-rays

According to testimony given, the standard for judgment to use or not to use X-rays on a patient is left to the professional opinion of the licensed physician. This has been the historical and workable solution to the question of who should decide how much radiation to give a patient. Given this approach, other problems arise, as the hearings brought out. All physicians are not equally cognizant of the risks of radiation. To what extent should a physician be required by law to invest in filters, shielding, and other equipment for his apparatus? Should a physician be required by law to make dose measurements and to submit reports to local or State agencies? The present goal for medical X-ray exposures would appear to be to strike a balance between giving people a reasonable degree of protection from unnecessary radiation exposure, on the one hand, and minimizing problems such as those sketched here, on the other.

Because of the widespread and well-deserved interest being taken in problems of medical exposure, and because—as shown in table II—medical exposure is by far the largest source of manmade radiation exposure, a substantial portion of the testimony of Dr. Richard Chamberlain on this subject is quoted below:

> The medical uses of radiation have been so vitally important, and increasingly so, during the past half century, that much of the development of protection concepts has been shaped by the needs and special problems of these uses. It is not surprising that all the answers for the protection problems of the rapidly expanding nuclear age have not been apparent in the standards conceived primarily for these medical applications. The situation has been one, rather, in which standards or guides for prudent action have been constantly improved as radiological techniques and knowledge have shown their feasibility and need. It

is also true that the development of atomic energy has itself directly complicated the medical uses, but has also had considerable influence on the thinking of the medical profession about appropriate levels of exposure and the control of exposures.

In two ways, however, the medical uses of radiation merit special attention in discussions of future control criteria. The first is in regard to a sense of perspective in amounts of radiation which may be used or must be used for sufficiently useful purposes with the concepts of value judgments on which such choices are based. The second is the obligation to avoid unwarranted or excessive restrictions which may result in well-intentioned but finally harmful end results rather than the desired good effect.

The practical decisions in medicine which indicate the use of radiation are complex and varied in respect to amount of radiation used, the relative dosage to different parts of the body, the type of diagnostic or therapeutic benefit expected, and the potential seriousness of the disease or condition which is being dealt with. In almost every instance value judgments are required and it is impossible with present knowledge to be precise in the expression of more than one or two parameters.

* * * * * * *

The many variations of these situations have widely different radiation exposures, widely different urgency of medical need, and most often the precise risks and benefits are not definable, but must be weighed with an educated and experienced judgment, tempered with conservative concern for the patient's welfare. This is also the process by which the great majority of all medical value judgments are attained and is not unique to radiation. It equally applies to most of our use of effective medications, from aspirin to antibiotics and cytotoxic agents, the enlightened use of surgery, and the interpretation of other diagnostic methods on which definitive action is based.

It is germane to the discussion of radiation standards, however, because in all of these situations, while greater knowledge of risk and benefit is highly desirable and determinedly pursued, action is forced with admittedly incomplete understanding. It is my opinion that a great number of nonmedical uses of radiation are equally important to the total welfare of our people and equally justifiable for continued use on a comparable basis. Furthermore, this basis can be justified on a graded scale, weighing probable benefit versus probable risk without the necessity for absolute values for either. It is essential in doing so, however, that the criteria be under constant or periodic review and that they be interpreted by those with sufficiently broad knowledge of the factors involved to appreciate each type of situation from both aspects.

* * * * * * *

CONCLUSIONS

1. The past and present standards of the NCRP have been excellent for plan ning and as guides for good practice in the technical portions of medical as wel as other uses of radiation.

2. Difficulties arise in converting such guides for rigid legal and compensation limits of exposure. This is not only due to the methods of deriving the values and their uncertainties, but also to loss of sense of perspective when interpreted outside of a graded scale adjusted to need and benefit versus probable risks.

3. The experience derived from medical use of radiation suggests that many of the most important aspects of radiation control are not suitable to formal legislative regulation and must be approached with local interpretation by educated exercise of trained judgments.

4. Programs of education and improvement should be by long range planning so as to adapt to constantly changing knowledge and methods, not one-shot affairs.

5. Improvements are always possible and gradual shifts in criteria and guides should keep pace with them as well as scientific knowledge, but the present situation does not call for crash programs or overly rigid restrictions.

Radiation protection criteria and standards in relation to uranium mining

Mr. Duncan Holaday discussed in his testimony problems pertaining to uranium mining, where the working standard for air concentration of radon daughters has long been specified on a somewhat different

basis than would follow directly from NCRP recommendations. The committee feels that the following excerpts present the situation:

Maximum acceptable concentrations (MAC's) are an essential tool for the protection of the worker, as they represent a consensus of the best scientific opinion available. They prevent the development of the chaos that would result if each investigator had to rely on his own relatively limited experience and background. For governmental and official agencies who must visit many different operations in a year, they serve as a screening device to select those places which should receive further detailed study. For such use, the screening tool need not be highly accurate.

The staffs of official agencies are inclined to be too strict rather than too lenient and will usually attempt to study all operations where the threshold limits are exceeded.

For private industrial purposes, the MAC values serve as engineering bench marks. Where these values are used as a basis for the design of control procedures, they can be used with confidence as the usual engineering factors of safety are included in such specifications. For example, no industrial hygienist would specify a ventilation system that would collect only enough of the dust to maintain the atmospheric concentration at the MAC. His aim would be to maintain the concentrations well below the recommended MAC.

* * * * * * *

Much of the American Standard for uranium mines and concentrators is taken up with recommendations for interpreting the National Committee on Radiation Protection's MAC values for the elements of interest. In concentrators, it is recommended that a time-weighted average of the atmospheric concentrations of airborne dust over a period of 13 weeks be used to estimate the worker's exposures. This period was selected primarily for administrative convenience and not because of any particular virtue inherent in it. As methods of air sampling and survey procedures can seriously affect the values obtained, suggested methods and procedures were given. Parenthetically, I might comment that the correct determination of a time-weighted average atmospheric concentration is a time-consuming task that requires skill and experience.

After the weighted average concentrations are determined, decisions must be made concerning the meaning and use of these numbers. With nothing but the NCRP figures with which to compare the results of plant surveys, different interpretations would be made by different individuals, and therefore, a series of recommendations are made detailing actions that should be taken. To illustrate this point, the entire subsection is quoted:

"*Controlled condition:* If the 13-week weighted average exposure of the workers is below the MPC, the condition may be considered to be controlled and no action is necessary.

"*Partially controlled condition:* If the 13-week weighted average exposure of the workers exceeds the MPC but is less than five times this value, corrective action shall be initiated.

Unsatisfactory condition: If the 13-week weighted average exposure of the workers exceeds five times the MPC, immediate action shall be taken to reduce the worker's exposure and correct the condition."

This section of the standard is an example of a proper use of NCRP recommendations. It recognizes that the MPC values do not by themselves define safe or dangerous conditions, but that there are varying degrees of exposure to radioactive materials and that different actions should be taken depending upon the conditions existing in each individual situation.

These recommendations also infer that, in situations where the atmospheric concentrations vary, individual air samples, or even a limited number of air samples, are of dubious value in defining a worker's exposure. This subject is discussed more completely in other sections of the standard and appendixes.

Radiation protection criteria and standards in relation to fallout, aerospace development, nuclear accidents, and waste disposal

For a discussion of radiation protection criteria and standards in relation to fallout, aerospace development, nuclear accidents, and waste disposal, see the U.S. Naval Radiological Defense Laboratory preprint statement, excerpts of which appear in the appendix (p. 50).

There was discussion during the hearings and in the preprint on the applicability of existing ICRP–NCRP recommendations and FRC guides to fallout situations. Dr. G. Failla's preprint statement discussed the applicability of NCRP–ICRP recommendations to fallout:

> I believe that radiation exposure due to fallout should not be considered in the framework of NCRP or ICRP recommendations because they were never intended to apply to this problem. The testing of nuclear weapons constitutes an exceptional situation of a temporary nature involving national policy at the highest level. As such it should have been handled by such a body as the recently established Federal Radiation Council.

Secretary Flemming was asked about the meaning of the phrase "normal peacetime operations" as it appears in the Council memorandum. Does it cover, for example, the discharge of radioactivity from submarines, nuclear rockets, and weapon explosions? He replied as follows:

> * * * I would say that this question has been raised enough times that I think it would be wise for us to define it further * * *.

The impact of increasing radiation exposure levels

The subcommittee asked witnesses to consider a related question which should concern the Government and the public over the next decade and longer: How can the Nation (and the world) deal with an environment involving constantly rising levels of potential radiation exposure to the human population? The tendency among most witnesses addressing themselves to this question was to assume that basic radiation protection dose standards for the country would be set covering all peaceful (or peacetime) sources of exposure and that this total would, if necessary, be allocated among these sources. Thus, if fallout became excessive, waste disposal or power reactor development might have to be curtailed. But the witnesses did not indicate how such an in toto standard might be established, involving as it would a decision over all the (peacetime) uses. Such a standard would appear to be almost as fundamental an aspect of national policy by the year 2000 as the dollar budget is now.

An alternative to this pie-cutting (quota-allocation) approach is to set separate standards in each of several major areas of atomic energy use. A major problem with this approach is how to make meaningful measurements in the environment, but this problem received little discussion.

A strong indirect support to this latter approach was set forth in testimony stating that the FRC should, on an independent and ad hoc basis, consider the merits of introducing any major new source of exposure that might come along. In the foreseeable future, it would appear that most of these new sources will be from military and civilian aerospace sources. Civilian (commercial) sources can be expected to increase gradually but will perhaps not greatly differ in kind (powerplants, isotope uses, etc.) at least for some time to come.

It would seem that this question needs further attention. It has a bearing in relation to the activities of the Federal Radiation Council.

Establishment of the Federal Radiation Council

On August 14, 1959, Executive Order No. 10831 was issued establishing the Federal Radiation Council with the following statement of duties.[21]

[21] The full text of the Executive order appears in the hearings, p. 501.

The Council shall advise the President with respect to radiation matters directly or indirectly affecting health, including matters pertinent to the general guidance of executive agencies by the President with respect to the development by such agencies of criteria for the protection of humans against ionizing radiation applicable to the affairs of the respective agencies. The Council shall take steps designed to further the interagency coordination of measures for protecting humans against ionizing radiation.

At the same time the White House issued a press release discussing the Executive order and setting forth a series of related recommendations approved by the President. The following excerpts pertain to the Federal Radiation Council:[22]

The President announced today organizational arrangements aimed at centralizing responsibility for providing general standards and guidance to executive agencies for their use in developing operating rules and regulations for radiological health protection.

In order to obtain assistance in the discharge of this function the President has issued an Executive order establishing a Federal Radiation Council. Members of the Council are the heads of the agencies most significantly involved with radiation—the Secretary of Health, Education, and Welfare, the Chairman of the Atomic Energy Commission, the Secretary of Defense, and the Secretary of Commerce. The President's Special Assistant for Science and Technology will participate as an adviser in the discussions of the Council.

* * * * * * *

The Federal Radiation Council will also take steps designed to further the interagency coordination of measures for protection against radiation, and to that end will consult with all Federal agencies which have radiological health responsibilities.

On August 22, 1959, the White House issued another press release stating that Secretary of Health, Education, and Welfare Arthur S. Flemming had been designated Chairman of the FRC and setting forth additional responsibilities to be performed by the Department of Health, Education, and Welfare as follows:[23]

The President also directed that the Department of Health, Education, and Welfare intensify its radiological health efforts and have primary responsibility within the executive branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial use of isotopes and X-rays, and fallout, so that the Secretary of Health, Education, and Welfare may advise the President and the general public.

The Joint Committee on Atomic Energy, on September 2, 1959, reported out a bill (H.R. 8755 and S. 2568), later enacted as Public Law 86–373, which provided a statutory basis for the FRC. That law in part states:

h. There is hereby established a Federal Radiation Council, consisting of the Secretary of Health, Education, and Welfare, the Chairman of the Atomic Energy Commission, the Secretary of Defense, the Secretary of Commerce, the Secretary of Labor, or their designees, and such other members as shall be appointed by the President. The Council shall consult qualified scientists and experts in radiation matters, including the President of the National Academy of Sciences, the Chairman of the National Committee on Radiation Protection and Measurement, and qualified experts in the field of biology and medicine and in the field of health physics. The Special Assistant to the President for Science and Technology or his designee, is authorized to attend meetings, participate in the deliberations of, and to advise the Council. The Chairman of the Council shall be designated by the President, from time to time, from among the members of the Council. The Council shall advise the President with respect to radiation matters, directly or indirectly affecting health, including guidance for all Federal agencies in the formulation of radiation standards and in the establishment and execution of

[22] The full text of the press release appears in the hearings, p. 592.
[23] Full text of the press release appears in the hearings, p. 594.

programs of cooperation with States. The Council shall also perform such other functions as the President may assign to it by Executive order.[24]

The report accompanying H.R. 8755 and S. 2568 contained the following language:

It is hoped that this Council will assist in obtaining uniformity of basic standards among Federal agencies, as well as in programs of cooperation with States. The Council, as established in the bill, increases the membership from four to five, including the original four members and the Secretary of Labor, or their designees, and such other members as shall be appointed by the President. The President, if he deems it appropriate may appoint representatives of the public, or State or local agencies. The bill provides that the Council shall consult qualified scientists and experts in radiation matters, including the President of the National Academy of Sciences, the Chairman of the National Committee on Radiation Protection and Measurement, and qualified experts in the field of biology and medicine, and in the field of health physics.[25]

Based upon these enabling documents, it appears that the two primary functions assigned to the FRC were—

(1) to advise the President on radiation protection matters; and

(2) to coordinate radiation protection matters within the executive branch of the Federal Government, especially with respect to—

(a) Uniformity of radiation protection standards; and

(b) Federal-State cooperation.

First actions of the Federal Radiation Council

The first memorandum from the Federal Radiation Council to the President was approved on May 13, 1960, by the President for the guidance of Federal agencies. At the same time, the Council issued its Staff Report No. 1 on background material for the memorandum. Following a few pages of preliminary discussion, the memorandum makes seven recommendations concerning exposure of persons to radiation.[26] The discussion in the memorandum and the Staff Report No. 1 [27] views the setting of radiation protection standards as making a judgment on the extent to which society will accept exposure to radiation in order to realize benefits associated with the exposure. The discussion also summarizes portions of what is known about the biological effects of radiation and describes the biological basis for the approach FRC has taken in the memorandum. The Council emphasizes that there should be no single acceptable or permissible exposure level set without regard to the reasons for permitting the exposure, and that the extent to which people should be exposed to radiation should be decided on the basis of expected benefit in relation to hazards.

The seven recommendations of the memorandum include recommending the use of the new terminology "radiation protection guide" and "radioactivity concentration guide" in recognition of the fact that words such as "maximum permissible dose" and "MPC" have had unfortunate connotations not intended by the NCRP or ICRP. Using the new terminology, the FRC's third recommendation centers around a table of numbers for individual and population radiation exposure. These numbers are essentially the same as current numbers in the recommendations of the NCRP and ICRP. As discussed

[24] Sec. 274h of the Atomic Energy Act of 1954, as amended.
[25] H. Rept. No. 1125, 86th Cong., 1st sess., Sept. 2, 1959, p. 9. S. Rept. No. 870, 86th Cong., 1st sess., Aug. 31, 1959, p. 9.
[26] See p. 47.
[27] Hearings, p. 623.

earlier in this summary-analysis, it is not to be inferred, however, that because the numbers are the same, the implications of the FRC guides are identical to the implications of the NCRP–ICRP recommendations. The associated language differs.

The issuance of the FRC memorandum and staff report had the effect of altering somewhat the planned course of these hearings. The hearings provided an opportunity for discussing not only the meaning and effects of the memorandum and staff report but also the activities and plans of the Council. Witnesses from the Bureau of the Budget and the FRC reviewed the history and development of the Council and discussed its role, its method of operation, the practical effects of the Council's memorandum, and the future role of the President and the FRC. During the course of the hearings the Council and the Council's memorandum were often discussed, and major questions concerning the Council and how it operates and what its reports mean were posed by the committee and by witnesses.

Responsibility for radiation protection standards within the Federal Government

One of the prime concerns of the subcommittee was to determine the source and path of authority pertaining to existing and future Federal radiation protection policies, practices, and standards as well as the manner in which responsibilities in this field are discharged at the Federal level. The creation of the Federal Radiation Council had been interpreted by some witnesses as meaning that the President would exercise direct control in this field with the assistance of the Council and thus that memorandums or reports issued by the Council and approved by the President would constitute a mandatory framework within which all Federal agencies should operate.

Mr. Elmer Staats, of the Bureau of the Budget, testified that the purpose of the FRC and the function of the President is to provide a common basis for the operational standards of the Federal Government, with the standards themselves being developed and promulgated by the individual agencies. This arrangement was described by Mr. Staats as "both feasible and desirable."

In summary, Mr. Staats stated:

> In the final analysis the responsibility for operating standards lies with the particular agency involved. Under present circumstances we can foresee no legal or administrative problems in this regard.[28]

The particular guides contained in the first FRC memorandum and issued to all Federal agencies by the President were characterized by Mr. Staats as "a manifestation of Presidential leadership and direction over the affairs of the executive branch."

Effect of the FRC's first memorandum

Individual Federal agencies developing and promulgating radiation protection standards apparently are little affected by the one memorandum issued to date by the FRC except with respect to the new terminology recommended in that memorandum for general use by Federal agencies.

As Mr. Staats, of the Bureau of the Budget, stated the direction and guidance furnished to the agencies by the FRC, in the name of the President, "provides for the exercise of judgment on the part of

[28] Hearings, p. 442.

the recipients." The guidance, according to Mr. Staats, "embodies sufficient flexibility to accommodate" the statutory obligations for safety standards residing in the agencies.

The fact that the FRC guides do not seem to afford positive direction to the agencies was cited by several witnesses as the main shortcoming of the FRC. Dr. Charles R. Williams, for example, expressed the view that the FRC should concern itself with high policy decisions which would have the effect of removing the basic value judgments from the agency level, but leave the setting of actual numbers to the agencies themselves.

Dr. Williams stated:

> I had great hopes with the establishment of the Federal Radiation Council that we were going to see here a policymaking body which was going to attempt to answer these questions * * *. We already have technical groups setting up numbers. Certainly the Federal Radiation Council to date is adopting and utilizing all of those numbers which are now available. There is no reason why this should be different because these numbers have been gone over and over and over again, the same general conclusions seem to be arrived at.
>
> One missing fact is, what do we stack these numbers up against? We meet this every day in our practice of trying to provide radiation protection. What is the other side of the coin? I believe that the Federal Radiation Council could do a great service to this country if they would face these problems first, rather than going into the numbers which we already have and are using.[29]

The task to be performed was clearly recognized by FRC Chairman Flemming, but the implication of his testimony was that the FRC will leave this task to be performed by the various affected Federal agencies. Said Mr. Flemming:

> It is clear that the formulation of radiation protection standards involves a balancing of the risks to man of exposure to ionizing radiation against the benefits to be derived from the many important usages to which radiation is applied. The staff of the Council conducted a careful review of the current information on the hazards of ionizing radiation. As recommendations were being developed, each agency examined the basic assumptions, definitions, and recommendations in light of its statutory responsibility.

The seventh and final recommendation of the memorandum states:

> It is recommended that:
>
> 7. The Federal agencies apply these "Radiation Protection Guides" with judgment and discretion, to assure that reasonable probability is achieved in the attainment of the desired goal of protecting man from the undesirable effects of radiation. The guides may be exceeded only after the Federal agency having jurisdiction over the matter has carefully considered the reason for doing so in light of the recommendations in this paper.
>
> The "Radiation Protection Guides" provide a general framework for the radiation protection requirements. It is expected that each Federal agency, by virtue of its immediate knowledge of its operating problems, will use these guides as a basis upon which to develop detailed standards tailored to meet its particular requirements. The Council will follow the activities of the Federal agencies in this area and will promote the necessary coordination to achieve an effective Federal program.

Several witnesses at the hearings expressed doubt as to the meaning or effect of the guides contained in the memorandum in view of this final provision. To permit each agency to exceed the levels set forth if its reason for doing so is "carefully considered" is simply avoiding the issue, according to the testimony of one witness.

FRC Chairman Flemming testified that the Council would evaluate the actions of the agencies and advise the President if "those actions are in any manner inconsistent with the policy guidance of the Pres-

[29] Hearings, p. 302.

ident. * * *" He added, however, "It will be up to the President, of course, to take action." [30]

Further testimony by Chairman Flemming indicated that the extent of any policing or review function which the FRC might perform would be to serve as a central coordinating point in the executive branch for agencies affected by the memorandum. Agencies would report to the Council on their activities in relation to the FRC memorandum.

From the testimony presented, it is not clear just where final responsibility rests for the radiation protection standards which the agencies develop and promulgate and which the FRC intends to review through an examination of reports from the agencies. Clearly, the mechanism leading to any Presidential action pursuant to the advice of the FRC will be the FRC itself.

An important question is whether the FRC is in fact an agency performing a policing, review, or coordinating function within the executive branch, and is held responsible for this function, or is merely advisory to the President, in whom complete responsibility resides. Does the fact of a Presidential signature on FRC memorandums change the practical functions performed by the FRC?

The importance of establishing clear and final responsibility and authority for radiation protection criteria in the executive branch was underscored at the hearings by subcommittee questioning on the general subject of quota allocation of a population exposure limit among the various agencies. Thus far, each agency affected by the FRC guides has been given the entire range of the guides within which to set its standards. As mentioned earlier, attention should be given to this question before environmental contamination levels have risen to levels corresponding to the exposure guides. For example, is allocation a desirable approach?

Chairman Flemming's commentary on this problem indicates the need for clarification of the actual responsibility of the FRC. Mr. Flemming stated:

> * * * I agree * * * completely, and it seems to me that if, as a result of the operations of the Council, it becomes clear to us that a particular agency is going beyond what you and I might feel was a reasonable quota in that particular area of life or that particular activity, then it seems to me that there would be a responsibility resting on us to suggest to the agency that we did feel that way about it. We would have to make it perfectly clear to the agency that all we were doing was making a suggestion. If, however, it became rather clear that the agency did not intend to follow that suggestion, then we would have an obligation to make a report to the President with a recommendation. It would be up to the President to determine whether or not he was going to issue a directive to that agency. In other words, the Council, in my judgment, should never attempt to issue a directive; but I think that the Council should never hesitate to recommend to the President that he issue a directive if, in our judgment, that is the thing that is necessary in order to accomplish his overall objectives.

FRC–NCRP relationships

Consideration of whether the FRC is performing its originally intended functions inevitably raises questions with respect to the relationship of the FRC to the National Committee for Radiation Protection and Measurements (NCRP), whose recommendations and long history of valuable service in the radiation protection field were

[30] Hearings, p. 531.

discussed at length by many of the expert witnesses at subcommittee hearings.

Aside from the numerical similarity of the FRC guides and NCRP recommendations, some witnesses expressed the view that FRC activities to date were essentially a duplication of the NCRP effort. Many NCRP members were called upon by the FRC to consider questions previously considered by the NCRP and the answers developed did not differ from the NCRP answers. Furthermore, it is evident that the FRC, in preparing staff report No. 1, drew heavily on the extensive studies of NCRP and ICRP. Moreover, the evidence presented at the hearings indicates that the FRC findings—incorporated in the Presidential memorandum—have had the same effect as the earlier NCRP recommendations. The major Federal agencies affected by the memorandum have not been required to change their regulations or alter the numbers reflected in their radiation protection standards because they were already following the NCRP recommendations.

FRC Chairman Flemming noted that his agency, the Department of Health, Education, and Welfare, currently uses the NCRP recommendations.[31]

Whether the FRC has solved any major problems to date, was a question of less concern to many witnesses than the basic question of what will happen to the NCRP now that the FRC has been established. This is actually a two-part question: (*a*) What role will the NCRP perform in the future? (*b*) Will there be any bar to membership and full participation on the NCRP by employees of the Federal Government, particularly those individuals long active in the NCRP who are now being called upon, directly or indirectly, to work in support of the FRC?

Chairman Flemming agreed with other witnesses that the NCRP has performed a valuable service and expressed his hope that nothing would be done to cause a decline in either the activities or the influence of the NCRP. He also stated his view that the NCRP should continue to receive the benefit of the experience and contact with governmental problems which the membership of Federal employees provides.

Members of the Special Radiation Subcommittee expressed agreement with this view. It is generally agreed that the NCRP should not only continue to perform its traditional functions of scientific study and evaluation of technical data, but that it should retain its independence, unhampered by Government, industry, or any other interested group. It is believed important that any question of conflict of interest with respect to the active participation in NCRP affairs of scientists who are Government employees be resolved without delay.

The value of NCRP recommendations has been due in no small measure to the fact that they have represented a consensus of the scientific community, formulated by an independent association of respected representatives of that community.

At the same time, the NCRP has been accorded a degree of recognition by the Federal Government, by virtue of (i) the widespread official use of NCRP recommendations as authoritative; (ii) the publication of those recommendations in National Bureau of Standards Handbooks; (iii) funds provided for travel and miscellaneous expenses; and (iv) official participation by Government personnel in NCRP activities.

[31] Hearings, p. 539.

Procedural problems including staffing of the FRC

Presidential approval of the first FRC memorandum, and the subsequent issuance of the memorandum to Federal agencies as official policy, focused attention on the fact that the FRC functions outside the scope of the Administrative Procedures Act of 1946. Unlike administrative and regulatory agencies of the executive branch, the FRC is not required to have and does not have formal hearing procedures and mechanisms of appeal available for parties which might be adversely affected by its decisions.

Nor is the makeup of the FRC broadly representative in nature. There is no assurance that FRC decisions will always take into consideration the many points of view that might bear on its actions, beyond that afforded by the agencies whose heads make up the Council.

Despite assurances from executive branch witnesses that each Federal agency, in applying the FRC guides to its own regulations and operations, would be required to make its own findings and operate according to established administrative procedures, these questions were not fully resolved at the hearings.

On the question of representation, several witnesses suggested that the membership of the FRC be expanded to include additional representation, such as that of other additional Federal agencies and public and private interests as well. Furthermore, the question of providing proper representation of relevant scientific and legal disciplines, particularly economics, social sciences, and regulatory law, was raised. Some witnesses did not make a distinction between representation of points of view as a matter of democratic process and representation of appropriate legal and scientific disciplines. However, witnesses suggested that economic and social factors should be considered by the FRC at the working level in formulating policies and guides.

Dr. Allen V. Astin, Director of the National Bureau of Standards, and chairman of the FRC "working group," testified that the main emphasis of this group thus far has been "to put together the best technical recommendations we could find," and after that consideration of the broader issues took place at the Council level after completion of the working group effort. It may be noted that the Council in turn refers the broader factors to the member agencies. Said Dr. Astin:

> Each of the Council members was asked as an agency head, before he gave his final approval to the recommendations which the Council evolved, to consider all of the broader factors which are within the area of responsibility of the members represented on the Council.[32]

FRC Chairman Flemming conceded that further attention needs to be given to this question. He emphasized the fact that an effort was made to have the Council members view proposals in the light of broad considerations but he noted further that:

> * * * I think looking to the future that a good deal could be said for consulting some people who are specialists, experts in these areas, outside of Government. I think the point that has been made is a good one.[33]

Dr. Astin's testimony, above, raises the further question of staffing the FRC and how the FRC does its work. What does the "working

[32] See hearings, p. 538.
[33] Ibid.

group" do? What do the "temporary staffs" do? What are the relationships of the executive secretary (cited as the only full-time staff member of the FRC other than secretarial-clerical persons), the "temporary staffs" and the "working group" to each other and to the Council? Where does professional consideration of the highly complex technical problems, including economic and social problems, take place? It seems to be unanswered whether the FRC is a broad policy group, considering primarily social and economic factors, or a group to take detailed assessments of the biological hazards of radiation made by others and translate them into exposure guides in some, but not all, ways similar to NCRP–ICRP recommendations. Staff Report No. 1 does not clarify this question.

It would appear that answers to questions such as these are necessary to a determination of the permanent staffing needs of the FRC. Furthermore, the answers would seem to be bound up with the way the FRC goes about its work under its terms of reference.

A final procedural point of special interest to the committee concerns the extent to which the FRC as advisers to the President will decline to furnish information to the Congress. The first memorandum and staff report suggest that the FRC includes within its scope of inquiry much information in the field of radiation protection that is not of itself advisory or even policy in nature.

Problems in devising regulations

Testimony presented at the hearings indicated that the major difficulty in translating NCRP recommendations into legal status apparently lies in the fact that such use of the recommendations is not compatible with the philosophy and rationale of the recommendations themselves. The NCRP numbers are recommended for broad guidance in making decisions in radiation protection programs, and when the numbers are to be used in specific applications consideration should be given to the rationale behind the numbers.

At the same time, despite the difficulty of adapting general recommendations to specific applications, legal requirements of State and Federal agencies for the protection of workers and the public appear to necessitate a rather rigid codification of numbers into laws.

NCRP Chairman Lauriston Taylor stated that NCRP had considered its recommendations as general guides, largely educational in nature, which could be "adjusted and used with discretion according to whatever the circumstances demanded." It did not favor incorporating its recommendations into legal codes.

With respect to this point, Mr. Taylor provided the following commentary in his testimony:

> The first serious difficulty in this regard came about with the establishment by the Atomic Energy Commission of sharply drawn protection rules essentially making law out of such quantities as maximum permissible doses or maximum permissible concentrations.
>
> This remark is not intended to be critical of the AEC; they felt that the Atomic Energy Act of 1954 compelled them to take such action. Once it has been decided that there shall be regulations then it has been thought necessary to put them in legal form with a plug for every loophole.
>
> From a legal point of view this is completely understandable even though scientifically it may make little sense. Nevertheless such action has led to the development of unnecessarily restrictive criteria in many instances, and has removed from both the regulator or the user the opportunity of using judgment.[34]

[34] Hearings, p. 55.

As discussed earlier, the Federal Radiation Council has set forth its "Radiation Protection Guides." These guides are more official in character and as such are not purely recommendatory, although, as discussed earlier, a big question remains as to how binding the guides are. Therefore it would appear that a somewhat similar problem still exists as to how to go from the guides to working regulations.

Another problem cited by Mr. Taylor was that of attempting to use recommendations for purposes or classes of problems for which they were not intended, which has resulted partly from a need for information which did not exist.[35] Said Mr. Taylor:

> Recommendations designed for one class of problem when extrapolated to other classes of problems have resulted in concepts that may be unnecessarily restrictive.
>
> On the other hand there are instances where protection criteria designed for application to the adult have been applied to population groups involving children, in which case the results may be insufficiently restrictive.[36]

From the standpoint of a regulatory agency, the nature of radiation hazards presents complicated problems in the application of any recommended radiation exposure limits. Assuming that any level of exposure involves a hazard and that increased periods of exposure increase the hazard it should be recognized that recommended limits must apply to levels as well as to specific periods of time. To set a particular level for a given time period requires a determination that the additional effort required to achieve a lower level would not be justified by the increased protection which would thereby be achieved.

Mr. William F. Finan of the Atomic Energy Commission commented that while this approach may be appropriate in the case of NCRP recommendations, it presents difficulties for Government agencies responsible for administering radiation protection programs. Said Mr. Finan:

> On the one hand, the NCRP recommendation could be interpreted to permit larger exposures to the employees working around an experimental reactor than to those operating a standardized power reactor. On the other hand, if the recommendation should be coupled with the policy that no one atomic energy worker should be exposed to a greater radiation hazard than another, one would be faced with a dilemma in the shape of a limit which would be either unattainable for some applications or unnecessarily high for others.[37]

Mr. Finan also testified that comments received by the AEC from interested parties concerning the proposed revision of AEC regulations on radiation protection (10 CFR 20) challenged the use of NCRP recommendations in these regulations. He stated:

> The view was expressed that the NCRP recommendations are valuable for scientific purposes but are not adaptable to rulemaking. This group of comments included suggestions that the standards should be published as guides rather than as binding rules.[38]

Despite extensive testimony on the difficulty of translating NCRP recommendations into binding regulations, none of the witnesses at the hearings was able to suggest a workable alternative. The main question, as Dr. Forrest Western noted, is whether one wishes to work on the basis of recommendations or whether it is necessary to exercise legal control over a process. The Atomic Energy Commission, it

[35] This, of course, would be an expected outcome of the confused situation as to the purpose and meaning of the recommendations, as previously discussed.
[36] Hearings, p. 55.
[37] Hearings, pp. 146–147.
[38] Hearings, p. 151.

was pointed out, is in the position of exercising legal control over the uses of certain radioactive materials, and in an effort to do so it has taken the best available recommendations and drawn up regulations with as little distortion of the original intent of the recommendations as possible.

It was pointed out also that substantial differences exist between the type of activity that goes into the development of NCRP recommendations and the process by which standards are developed by the American Standards Association, another important group in radiation standards work. The ASA, it was noted, is engaged in the formulation of general standards which do not require the basic effort that characterizes much of the NCRP work. Moreover, although both NCRP and ASA work through committees, the ASA committee effort is subject to much greater revisions by member groups of ASA. In contrast, the final committee effort of the NCRP becomes the published NCRP recommendations, usually in the form of National Bureau of Standards Handbooks.

The work of the American Standards Association was described by Dr. Charles R. Williams as follows:

> ASA * * * not only has its committees and subcommittees reach agreement, but their work must be approved by their sponsors and, furthermore, a finished standard must be submitted to an appropriate standards board—in the case of radiation, the Nuclear Standards Board—which must determine that there is a consensus among all interested groups and individuals before any standard can be accepted as an "American standard." When dealing in areas where there may be differences of opinion as to philosophy and wholly inadequate factual material to support one side or the other it is extremely important that some sort of consensus be reached among the authorities in any area before a standard can be acceptable.[39]

Need for flexibility

While the need for regulations governing radiation exposures of all types was recognized by all witnesses who testified on this point, several witnesses stressed the importance of avoiding undue rigidity in the formulation and application of regulations. It was pointed out that from a regulatory standpoint it is much easier to use specific numbers or other such rigid criteria in checking on compliance with safety requirements, but the use of such criteria in not always suitable in the field of radiation protection.

Mr. Duncan Holaday, for example, noted that it is a simple matter to determine whether a saw is guarded or unguarded, or to ascertain that an atmospheric sample is above a certain concentration. It is much more difficult to demonstrate that a 13-weeks weighted average exposure is above a certain concentration, and it is almost impossible, he noted, to prove that a person's exposure has been above a certain number that might be specified in regulations.[40]

Other testimony indicated that in actual practice, AEC enforcement of radiation protection standards is quite flexible despite the rigidities of part 20 of the Code of Federal Regulations. In the case of accidental exposures, which are required to be reported to AEC, or when AEC finds that an operation is routinely exceeding the limits specified in part 20, certain corrective actions are prescribed for the operations of the licensee. There is not an automatic revocation of license or suspension of operations, although either action may be

[39] Hearings, p. 127.
[40] Hearings, pp. 429–430.

taken. Usually the AEC will impose tighter restrictions for a specified period of time during which adjustments can be made to remove or reduce the hazard to an acceptable level.

Mr. Holaday suggested that numbers for maximum allowable concentration generally not be put into legal regulatory codes, but that actual situations be evaluated as a matter of professional judgment. All available techniques of evaluating exposure hazards should be used, he said, including many existing guidelines and numbers, without placing undue reliance on any given table of numbers.

In summary, Mr. Holaday stated:

> * * * Tables of MAC values are an indispensable tool in the field of radiation protection. They assist in the design of control equipment and operational procedures and serve as a check on the effectiveness of such measures. They are recommendations based on the best information available and should be considered as such. They should not be allowed or assisted to enter into legal regulatory codes as the sole definition of a satisfactory or unsatisfactory condition, and should be interpreted only by those who are capable of evaluating all of the factors which may be present in any situation. No handy list of numbers can be expected to take the place of human judgment exercised by a trained and perceptive observer.

The upshot of the situation may be that at the same time the basic philosophy of radiation protection is cleared up, as discussed earlier, the philosophy of radiation protection in regulation form should be developed sufficiently flexibly so as to permit reasonable compatibility of legal, scientific, and policy needs.

State activities

At the present time State codes dealing with radiation protection serve two general purposes. In many cases, the main intent is to locate and sometimes to provide for the registration of radiation sources. Secondly, particular categories of activity are set forth for the application of specific rules of conduct.

Dr. Williams testified that the rules presently embodied in State codes are based on information developed by the NCRP and the ASA almost without exception.

The extent of State activities at the present time in the radiation field was summarized in the preprint statement of Dr. Morris Kleinfeld of the New York Department of Labor as follows:

> About 10 States have radiation protection codes. Nine additional States have no code but require registration of radiation sources. Eleven municipalities have drafted regulations for radiation protection and/or radioactive waste disposal. The radiation protection reglations adopted thus far are entirely consonant with the pertinent NCRP recommendations and AEC regulations.
>
> In March 1959, an office of atomic development headed by a coordinator was created in New York State by legislative enactment. The purpose of this new agency was to promote the development of the atomic energy industry and the uses of radiation, to coordinate the regulatory activities of the various State and local agencies, and to provide liaison with Federal agencies such as the AEC and Public Health Service. Thirteen other States have created similar agencies for these purposes.[41]

The AEC reported that an effort is being made at the present time to transfer jurisdiction to the States in some areas of radiation licensing matters under the terms of Public Law 86–373. At the time of the hearings no transfers had taken place, but it was expected that some

[41] Preprint, pp. 117–118.

States would enter into agreements to effect transfers in this field by the end of 1960.

The procedure for effecting these transfers was described by Mr. Finan as follows:

> It is contemplated by the statute that AEC will enter into an agreement with a State for the discontinuance of jurisdiction if the Governor of that State certified that the State has a program for the control of radiation hazards adequate to protect the public health and safety with respect to the materials within the State covered by the proposed agreement and that the State desires to assume regulatory responsibility for such materials; and the AEC finds that the State program is compatible with the Commission's program for the regulation of such materials, and that the State program is adequate to protect the public health and safety with respect to the materials covered by the proposed agreement.[42]

The fundamental importance of establishing realistic and workable radiation protection standards in the Federal program was underscored by the testimony of Mr. Finan, which indicated that in order for State programs to qualify for the transfer of jurisdiction, they must use radiation protection standards comparable to those used at the Federal level.

[42] Hearings, p. 150.

APPENDIXES

Appendix 1

Executive Office of the President,
Bureau of the Budget,
Washington, D.C., August 21, 1959.

Hon. Clinton P. Anderson,
Chairman, Joint Committee on Atomic Energy,
U.S. Senate, Washington, D.C.

My Dear Mr. Chairman: In my letter to you of May 6, 1959, I stated that you would be informed when the joint review of Federal organization of radiological health activities conducted by the Secretary of Health, Education, and Welfare, the Chairman of the Atomic Energy Commission and the Director of the Bureau of the Budget had been completed.

I would like to now advise you that the President has approved the following recommendations:

(1) The President provide general standards and guidance to executive agencies for their use in developing operating rules and regulations for radiological health protection.

(2) The President be advised by a Federal Radiation Council, established by the President to advise him regarding the general standards and guidance to be issued by the President, as well as other matters pertinent to radiological health, the Council to be composed of the heads of the agencies principally affected—AEC, HEW, Defense, and Commerce; and that the President's Special Assistant for Science and Technology serve as an advisor to the Council.

(3) The Department of Health, Education, and Welfare intensify its radiological health efforts and have primary responsibility within the executive branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical, and industrial use of isotopes and X-rays, and fallout, so that the Secretary of Health, Education, and Welfare may advise the President and the general public.

(4) The Atomic Energy Commission have the principal Federal responsibility for preparing the States for the proposed transfer of certain of its regulatory responsibilities.

(5) The training programs necessary for such transfer be financed and planned by the Commission, and, in order to make maximum use of existing facilities and competence, such programs be conducted under cooperative arrangements between the Atomic Energy Commission and the Department of Health, Education, and Welfare.

(6) At the termination of this special training program, any training of State personnel be conducted within the continuing programs of the Department of Health, Education, and Welfare and other Federal agencies.

(7) The Department of Health, Education, and Welfare continue as the Federal focal point for guidance and assistance to the States with respect to radiation sources not now under control of the Commission.

Recommendations (4) through (7) are to be carried out upon enactment of proposed legislation along the lines of S. 1987 and H.R. 7214.

Sincerely yours,

Maurice H. Stans, *Director.*

APPENDIX 2

FEDERAL RADIATION COUNCIL

RADIATION PROTECTION GUIDANCE FOR FEDERAL AGENCIES

MEMORANDUM FOR THE PRESIDENT

Pursuant to Executive Order 10831 and Public Law 86–373, the Federal Radiation Council has made a study of the hazards and use of radiation. We herewith transmit our first report to you concerning our findings and our recommendations for the guidance of Federal agencies in the conduct of their radiation protection activities.

It is the statutory responsibility of the Council to "* * * advise the President with respect to radiation matters, directly or indirectly affecting health, including guidance for all Federal agencies in the formulation of radiation standards and in the establishment and execution of programs of cooperation with States * * *."

Fundamentally, setting basic radiation protection standards involves passing judgment on the extent of the possible health hazard society is willing to accept in order to realize the known benefits of radiation. It involves inevitably a balancing between total health protection, which might require foregoing any activities increasing exposure to radiation, and the vigorous promotion of the use of radiation and atomic energy in order to achieve optimum benefits.

The Federal Radiation Council has reviewed available knowledge on radiation effects and consulted with scientists within and outside the Government. Each member has also examined the guidance recommended in this memorandum in light of his statutory responsibilities. Although the guidance does not cover all phases of radiation protection, such as internal emitters, we find that the guidance which we recommend that you provide for the use of Federal agencies gives appropriate consideration to the requirements of health protection and the beneficial uses of radiation and atomic energy. Our further findings and recommendations follow.

Discussion. The fundamental problem in establishing radiation protection guides is to allow as much of the beneficial uses of ionizing radiation as possible while assuring that man is not exposed to undue hazard. To get a true insight into the scope of the problem and the impact of the decisions involved, a review of the benefits and the hazards is necessary.

It is important in considering both the benefits and hazards of radiation to appreciate that man has existed throughout his history in a bath of natural radiation. This background radiation, which varies over the earth, provides a partial basis for understanding the effects of radiation on man and serves as an indicator of the ranges of radiation exposures within which the human population has developed and increased.

The benefits of ionizing radiation. Radiation properly controlled is a boon to mankind. It has been of inestimable value in the diagnosis and treatment of diseases. It can provide sources of energy greater than any the world has yet had available. In industry, it is used as a tool to measure thickness, quantity or quality, to discover hidden flaws, to trace liquid flow, and for other purposes. So many research uses for ionizing radiation have been found that scientists in many diverse fields now rank radiation with the microscope in value as a working tool.

The hazards of ionizing radiation. Ionizing radiation involves health hazards just as do many other useful tools. Scientific findings concerning the biological effects of radiation of most immediate interest to the establishment of radiation protection standards are the following:

1. Acute doses of radiation may produce immediate or delayed effects, or both.
2. As acute whole body doses increase above approximately 25 rems (units of radiation dose), immediately observable effects increase in severity with dose, beginning from barely detectable changes, to biological signs clearly indicating damage, to death at levels of a few hundred rems.
3. Delayed effects produced either by acute irradiation or by chronic irradiation are similar in kind, but the ability of the body to repair radiation damage is usually more effective in the case of chronic than acute irradiation.
4. The delayed effects from radiation are in general indistinguishable from familiar pathological conditions usually present in the population.
5. Delayed effects include genetic effects (effects transmitted to succeeding generations), increased incidence of tumors, lifespan shortening, and growth and development changes.

6. The child, the infant, and the unborn infant appear to be more sensitive to radiation than the adult.

7. The various organs of the body differ in their sensitivity to radiation.

8. Although ionizing radiation can induce genetic and somatic effects (effects on the individual during his lifetime other than genetic effects), the evidence at the present time is insufficient to justify precise conclusions on the nature of the dose-effect relationship at low doses and dose rates. Moreover, the evidence is insufficient to prove either the hypothesis of a "damage threshold" (a point below which no damage occurs) or the hypothesis of "no threshold" in man at low doses.

9. If one assumes a direct linear relation between biological effect and the amount of dose, it then becomes possible to relate very low dose to an assumed biological effect even though it is not detectable. It is generally agreed that the effect that may actually occur will not exceed the amount predicted by this assumption.

Basic biological assumptions. There are insufficient data to provide a firm basis for evaluating radiation effects for all types and levels of irradiation. There is particular uncertainty with respect to the biological effects at very low doses and low-dose rates. It is not prudent therefore to assume that there is a level of radiation exposure below which there is absolute certainty that no effect may occur. This consideration, in addition to the adoption of the conservative hypothesis of a linear relation between biological effect and the amount of dose, determines our basic approach to the formulation of radiation protection guides.

The lack of adequate scientific information makes it urgent that additional research be undertaken and new data developed to provide a firmer oasis for evaluating biological risk. Appropriate member agencies of the Federal Radiation Council are sponsoring and encouraging research in these areas.

Recommendations. In view of the findings summarized above the following recommendations are made:

It is recommended that:

1. There should not be any manmade radiation exposure without the expectation of benefit resulting from such exposure. Activities resulting in man-made radiation exposure should be authorized for useful applications provided in recommendations set forth herein are followed.

It is recommended that:

2. The term "Radiation Protection Guide" be adopted for Federal use. This term is defined as the radiation dose which should not be exceeded without careful consideration of the reasons for doing so; every effort should be made to encourage the maintenance of radiation doses as far below this guide as practicable.

It is recommended that:

3. The following Radiation Protection Guides be adopted for normal peacetime operations:

Type of exposure	Condition	Dose (rem)
Radiation worker:		
(a) Whole body, head and trunk, active blood forming organs, gonads, or lens of eye.	Accumulated dose.	5 times the number of years beyond age 18.
	13 weeks	3.
(b) Skin of whole body and thyroid	Year	30.
	13 weeks	10.
(c) Hands and forearms, feet and ankles	Year	75.
	13 weeks	25.
(d) Bone	Body burden	0.1 microgram of radium 226 or its biological equivalent.
(e) Other organs	Year	15.
	13 weeks	5.
Population:		
(a) Individual	Year	0.5 (whole body).
(b) Average	30 year	5 (gonad)s.

The following points are made in relation to the Radiation Protection Guides herein provided:

(1) For the individual in the population, the basic Guide for annual whole body dose is 0.5 rem. This Guide applies when the individual whole body doses are known. As an operational technique, where the individual whole body doses are not known, a suitable sample of the exposed population should be developed whose protection guide for annual whole body dose will be 0.17 rem per capita per year. It is emphasized that this is an operational technique which should be modified to meet special situations.

(2) Considerations of population genetics impose a per capita dose limitation for the gonads of 5 rems in 30 years. The operational mechanism described above for the annual individual whole body dose of 0.5 rem is likely in the immediate future to assure that the gonadal exposure Guide (5 rem in 30 years) is not exceeded.

(3) These Guides do not differ substantially from certain other recommendations such as those made by the National Committee on Radiation Protection and Measurements, the National Academy of Sciences, and the International Commission on Radiological Protection.

(4) The term "maximum permissible dose" is used by the National Committee on Radiation Protection (NCRP) and the International Commission on Radiological Protection (ICRP). However, this term is often misunderstood. The words "maximum" and "permissible" both have unfortunate connotations not intended by either the NCRP or the ICRP.

(5) There can be no single permissible or acceptable level of exposure without regard to the reason for permitting the exposure. It should be general practice to reduce exposure to radiation, and positive effort should be carried out to fulfill the sense of these recommendations. It is basic that exposure to radiation should result from a real determination of its necessity.

(6) There can be different Radiation Protection Guides with different numerical values, depending upon the circumstances. The Guides herein recommended are appropriate for normal peacetime operations.

(7) These Guides are not intended to apply to radiation exposure resulting from natural background or the purposeful exposure of patients by practitioners of the healing arts.

(8) It is recognized that our present scientific knowledge does not provide a firm foundation within a factor of two or three for selection of any particular numerical value in preference to another value. It should be recognized that the Radiation Protection Guides recommended in this paper are well below the level where biological damage has been observed in humans.

It is recommended that:

4. Current protection guides used by the agencies be continued on an interim basis for organ doses to the population.

Recommendations are not made concerning the Radiation Protection Guides for individual organ doses to the population, other than the gonads. Unfortunately, the complexities of establishing guides applicable to radiation exposure of all body organs preclude the Council from making recommendations concerning them at this time. However, current protection guides used by the agencies appear appropriate on an interim basis.

It is recommended that:

5. The term "Radioactivity Concentration Guide" be adopted for Federal use. This term is defined as the concentration of radioactivity in the environment which is determined to result in whole body or organ doses equal to the Radiation Protection Guide.

Within this definition, Radioactivity Concentration Guides can be determined after the Radiation Protection Guides are decided upon. Any given Radioactivity Concentration Guide is applicable only for the circumstances under which the use of its corresponding Radiation Protection Guide is appropriate.

It is recommended that:

6. The Federal agencies, as an interim measure, use radioactivity concentration guides which are consistent with the recommended Radiation Protection Guides. Where no Radiation Protection Guides are provided, Federal agencies continue present practices.

No specific numerical recommendations for Radioactivity Concentration Guides are provided at this time. However, concentration guides now used by the agencies appear appropriate on an interim basis. Where appropriate radioactivity concentration guides are not available, and where Radiation Protection Guides for specific organs are provided herein, the latter Guides can be used by the Federal agencies as a starting point for the derivation of radioactivity concentration guides applicable to their particular problems. The Federal Radiation Council has also initiated action directed towards the development of additional Guides for radiation protection.

It is recommended that:

7. The Federal agencies apply these Radiation Protection Guides with judgment and discretion, to assure that reasonable probability is achieved in the attainment of the desired goal of protecting man from the undesirable effects of radiation. The Guides may be exceeded only after the Federal agency having

jurisdiction over the matter has carefully considered the reason for doing so in light of the recommendations in this paper.

The Radiation Protection Guides provide a general framework for the radiation protection requirements. It is expected that each Federal agency, by virtue of its immediate knowledge of its operating problems, will use these Guides as a basis upon which to develop detailed standards tailored to meet its particular requirements. The Council will follow the activities of the Federal agencies in this area and will promote the necessary coordination to achieve an effective Federal program.

If the foregoing recommendations are approved by you for the guidance of Federal agencies in the conduct of their radiation protection activities, it is further recommended that this memorandum be published in the Federal Register.

ARTHUR S. FLEMMING,
Chairman, Federal Radiation Council.

The recommendations numbered "1" through "7" contained in the above memorandum are approved for the guidance of Federal agencies, and the memorandum shall be published in the Federal Register.

DWIGHT D. EISENHOWER.

MAY 13, 1960.

[F.R. Doc. 60-4539; Filed, May 17, 1960; 8:51 a.m.]

APPENDIX 3

ADAPTATION OF BIOLOGICAL INFORMATION TO THE DEVELOPMENT OF BASIC DOSE RECOMMENDATIONS

(Excerpt from preprint statement of Mr. H. M. Parker)

Early experiences provide the basis upon which the knowledge of the effects of protracted radiation exposure of man is founded. The present limits for radiation protection were derived from them in a manner completely analogous to that by which many of the standards for toxic chemicals were derived. In the period up to 1940, the principal information on the effects of external radiation came from four groups of exposed individuals.

These were—

1. Fluoroscopists who were exposed to short bursts of quite intense radiation at rates between 4–400 r/hour to the body;
2. X-ray therapy technicians who were characteristically exposed to radiation for periods of 5 to 30 minutes with intervals of the same order between treatments. Before self-protected tubes and special shields were used, the exposure rate for these individuals was on the order of 400 mr/hour.
3. X-ray therapy patients in which the dose rates were on the order of 40 r/hr for a total dose to the body of 80 to 120 r from scattered radiation and delivered over a period of weeks rather than years; and
4. Radium therapists and technicians who were exposed at rates on the order of 4r/hr for periods up to 1 hour at irregular intervals with an additional exposure from the background in the work area of perhaps 5–10 mr/hr through the working day.

During this period up to 1940, the limits for radiation were referred to as the "tolerance dose." This implied that there is a level of radiation exposure at which there is no lasting damage to the organism, presumably because the rate of repair is great enough and continues through the lifetime so that the damage is continually repaired.

The tolerance dose, 100 mr/day, used during the World War II period, was based on the experience with the radiation effects on people primarily occupationally exposed. Cantril and Parker pointed out at this time that the basic numbers available in 1945 which were accepted as a working basis for occupational exposure were—

1. 100 mr/day for external X- and gamma radiations;
2. 10^{-14} curies/cc for radon in the air of working rooms;
3. 0.1 ug of radium as the maximum allowable amount deposited in the body.

Each of these levels was established by applying a safety factor to the amount which had been observed to produce lasting injury to persons so exposed. At the time of this appraisal, the authors believed that the safety margin was considerably less than a factor of 10. It is true that these numbers were based upon limited

numbers of cases so that the statistics for applying to total damage with large numbers of people were poor.

Since this time there have been some changes in the limits, primarily on the basis of further observations of early patients given radium; of epidemiological studies following the uses of radiation in diagnosis and therapy; and of extensive animal experiments. The animal experimentation has been primarily useful in providing concepts rather than in providing information directly applicable to human limits, since the quantitative response of man to radiation is different from that of most laboratory animals. Thus, the concepts of life shortening, most of our knowledge of genetic changes, values for the relative biological effectiveness of different radiations, and the knowledge of the differential effects between radium and other bone seekers is based on animal experimentation. In the final analysis, however, these concepts are applied to man and the human maximum permissible limit through the basic information which has been developed in the limited experience with the effects on man.

In the period between 1945 and 1950, the information available on the genetic effects and the increasing suspicion that not all somatic effects of radiation were of a threshold type (i.e., of a type that requires a minimum dose before manifestation) led to the change in terminology from "tolerance dose" to the present "maximum permissible dose." It was at this point that the concept of acceptable risk appeared.

I am convinced that the terminology was changed from the one form to the other specifically to underline the acceptance of a no-threshold-dose concept for the production of gene mutations by radiation (p. 26 et seq. of Handbook 59). From a language point of view, one could equally well have been changing from a "maximum permissible dose" to "tolerable dose" or "tolerance dose." The intent to change to an "acceptable risk" line of reasoning was partially obscured by an arbitrary choice of words.

The fundamental change in approach at this point has not always been sufficiently emphasized. The earlier clinical observations clearly pointed to the existence of threshold effects and perhaps conditioned observers to expect all deleterious effects to have a threshold. It was, for example, palpably impossible to produce reddening of the skin with less than some prescribed dose. If such a threshold applied to every radiation effect, an intelligent, wholly technical, search could be made to define such thresholds with precision, and persons exposed to lesser amounts would be protected in the fullest sense.

If there is no threshold dose, there is no absolutely safe dose in the same sense. The determination of permissible limits, then, involves value judgments outside the areas of scientific and technical competence. It is essential that qualified observers continue to play a basic role in recommending standards. This follows from the principle of better acceptance of standards having the authority of knowledge, and from one further much-overlooked factor. This is that although present day standards appear to be established in detail by the considerations of physicists, biologists, and other scientists, they are basically validated by clinical experience. This experience does go beyond reproducible science and does include value judgments in accordance with the Hippocratic oath. Because some aspects of the genetic effects are beyond clinical observation, there is a needed separate voice of authority from geneticists. Then, because the decisions are necessarily based on cultural reactions to human welfare, many generations hence, the whole structure of ethical opinion must be included in some fashion.

The firm resolution of the evidence concerning the response at very low dose rate and low total dose as to whether relevant radiation effects are threshold, nonthreshold and linear, or nonthreshold and nonlinear is the most important factor, in effect, in establishing the authority of knowledge for radiation standards.

Appendix 4

Practical Applications of Radiation Protection Criteria and Standards

(Excerpt from preprint statement of the U.S. Naval Radiological Defense Laboratory)

The second point to be emphasized is that frequency and continuity in production of radiating materials is exceedingly important in establishing relevance to normal processes of living. For example, both the May 1959 hearings on weapon testing and the 1957 hearings on radioactive fallout indicated that short-lived

isotopes such as iodine 131, barium 140, etc., could become dominant factors at certain combinations of yield and frequency of release. Since such materials are not confined to generation by weapons, but can also be generated by one or a combination of devices employed for peaceful uses of nuclear fission, the requirement to evaluate, not only in terms of quantity, but also in terms of times and frequency, appears. It follows that a moratorium on weapon testing will not eliminate the problem of environmental radioactivity. As in the example of a "clean" weapon versus a "dirty" weapon, the problem may be changed, but it is not solved.

* * * * * * *

The aircraft nuclear propulsion program requires that pilots operating aircraft must exceed the average level accumulation rate of 0.1 rem/wk while operating the aircraft. The requirement is a military one, and it may be argued that normal criteria for exposure are not applicable. However, it may be argued alternatively that it requires only moderate increase in flexibility in the basic rules to operate within them. The principal alteration required is, that the time period over which the accumulated dose is accepted be adjusted. At a time when the weekly rate was set at 0.3 r, the ANP Advisory Committee recommended that pilots be allowed to accept a maximum of 25 roentgens per mission for a maximum of 8 missions. The question is, is this an unusual risk to these individuals since it implies acceptance of 200 roentgens over a moderately short period of time? Under the present regulation, a lifetime dose to age 65 would be: (65–18) 5 rem-235 rem. The crewmen have, then, not exceeded the lifetime accrual allowed, but they would necessarily be restricted from further exposure at the termination of their flight career. ICRP allows 12 rem on a nonrepetitive basis to be "worked off" in no more than 5 years. We feel that such restrictions cannot be accepted in a general sense, but must be made flexible to meet special needs. However, the controlling dose of (N–18) 5 rem should not be exceeded as far as lifetime accumulation is concerned.

Control of rate of accumulation is thought to be necessary because, on the individual basis, one other factor must be considered. This is "years at risk." The individual who accumulates 100 rem at age 25 has a greater risk of developing leukemia than an individual who accumulates 100 rem at age 70, merely because the time for development of the end point may not elapse before the effect becomes evident. We believe this to be a secondary consideration and violation of the principle of "level accumulation rate" will not lead to serious consequences.

The risk for the ANP pilots who accumulate 200 rem in 2 years, provided they have not been previously exposed and will not be subsequently exposed, is essentially the same as that of another individual of equal age who has managed to accumulate 200 rem over the preceding 15 years. The individual chances of the people involved in these two cases may be considered to be identical and there in no military risk involved greater than that which would be considered acceptable.

The principle involved here is that military exposures of a restricted group are not dominated by genetic considerations, but in fact are dominated by the individual risks to the personnel concerned. The contribution of these individuals to the genetic damage pool, particularly if exposure commences at age 30, is negligible. The laboratory sees no reason for controlling military applications within the rigors of industrially acceptable "annual dose rates" provided the accumulated lifetime exposure does not exceed that which would be compatible with the N–18 times 5 rule. Exposures in excess of otherwise controlling annual dose rates are in the interests of national security and justify specific treatment.

For exposure of large populations to circumambient levels of radiation, the prime industrial principle of radiation control, that is, controlled access, is not applicable. For this reason, criteria of exposure of large populations must be based, not on a maximum permissible exposure, but an average or expected exposure. The critical hazard in such case is of genetic injury, and the pertinent measure is the average gonadal exposure. This will seldom be known. NRDL feels that we should accept the ICRP's present decision to hold down the average by limiting the likely maximum among such uncontrolled groups of persons to 0.5 rem per year. The MPD is set higher in the industry (5 rem per year), not because they rate a higher level of radiation risk, but because their numbers are known and their opportunities for exposure are controlled. For exposure as an incident of employment, the frequency distribution is somewhat predictable, and control of average gonadal exposure by limiting industrial maximum individual exposure is satisfactory. From present observations with proper management under MPD of 5 rem per year, the industrial contribution to the U.S.-wide average gonadal dose would be only a fraction of the natural background, even if a million

men came to be employed in nuclear industry. This principle would suffice for the environs of nuclear installations as well, although NCRP and ICRP prefer to specify the 0.5 r per year maximum for such populations.

As we are discussing "likely dose" for the population, it can be seen that even if the population MPD is achieved, we will exceed natural background by a factor of three.

We arrive at two general points of decision for control measures in radiation protection:

a. The genetic dose (dose to gonads) from all sources, including military, industrial or occupational exposures should not exceed 500 mr/yr per individual on the average. It must be clearly understood that the occasional individual who exceeds this value contributes little to the population average, and does himself negligible harm.

b. Somatic exposure levels of 500 mrem/yr and 5 rem per year. The lower value is to be considered high with regard to normal environment and specific control measures should be instituted to lower them. However, negligible somatic injury to the individual is related to either 0.5 rem or 5 rem/year, and they are merely guideposts. In the specific case of strontium 90 body burdens corresponding with these values would be 170 and 1700 strontium units in bone.

Internal emitters.—The general criteria above are specifically applicable to the question of establishment of maximum permissible environmental concentrations of an isotope. The body burden necessary to give doses to the critical tissues equivalent to those mentioned in the preceding paragraph are calculated. From these values, and the best available data on modes of movement from source to tissue, the MPC may be established. The ICRP has suggested that the MPC for exposure of large populations shall be set at one-thirtieth of that for continuous occupational exposure.

Implications with regard to food, water, and air

The heart of the NRDL proposal for practical application is that genetic and somatic injuries are considered separately. Either can control. It is obvious that a whole host of separate "working standards" relating concentrations in food, water, and air to time and from here back to the annual sum will be needed. As has been pointed out, many already exist. Great care should be exercised in formulating regulations of this type, particularly if these are enacted into law. If fixed upper limits are based on the steady-state concentrations, economic penalties will be imposed by condemning food or water on the basis of inconsequential transient concentrations. Establishing a fixed "black or white" limit in preference to a graded decision procedure can lead to quite unnecessary exposures and consequent potential damage. Ill-advised laws can be dangerous to either the economy, to health, or to both.

In the case of strontium 90, attention is called to the point that absorption of this isotope is sensitive to the total strontium 90 content of the diet and the total calcium content. The strontium unit has no relevance to the strontium 90 problem in relation to public health and should not be used in this connection. Similarly, the strontium 90 content of any particular item of the food supply has no independent significance except as it relates to the annual food intake. Regulations or laws should take cognizance of the level, the percentage of food at that level, and the length of time it would have to exist in this combination.

5. EXAMPLES OF APPLICATION OF RADIATION PROTECTION STANDARDS

Several examples can be cited from Navy application to illustrate the use of these concepts: the handling of nuclear accidents (RadCon); the handling of contaminated ships, and some aspects of wartime policies as they illustrate corresponding peacetime events.

These examples illustrate how the choice of a particular criterion is dictated by the exigencies of the situation.

(*a*) *Nuclear accidents.*—The Navy radiological control (RadCon) teams must be prepared to render medical, monitoring, logistic and recovery assistance in accidents and incidents involving nuclear weapons, reactors and fissionable or radioactive materials. In an accident, control over materials has been lost or its loss is threatened. Biological risk may be expected, either in the immediate rescue of personnel in a contaminated area, or the requirement to halt or modify an industrial process or action which, if allowed to continue, may greatly increase the danger. In either instance, decisions will be reached on the basis of actual dose-effect tables. Exposures of 25 to 100 r to a limited number of persons are considered tolerable. The real risks come from the uncertainty in establishing

the radiological condition accurately enough to make sure that nobody gets 500 or 1,000 r.

Once the radiological situation is ascertained and emergency actions completed, the accident takes on the nature of a "special operation" and is handled in that manner.

A "special operation" is the management of an unusual situation with fairly high radiation levels which one expects to face only this once or a limited number of times.

In such cases one is prepared to exceed exposure limits recommended by the NCRP. Exposures are then accounted for quarterly, or yearly. Individual and group exposures are, of course, kept to a minimum by the use of controlled stay times in radiation areas, and the use of protective gear (respirators, special clothing) and devices (remote handling tools, radio-controlled mobile equipment, etc.). One aims to clean up the area and eventually return it to routine operation. After recovery one again applies stringent radiation-protection criteria.

(*b*) *Special operations.*—We have some experience in handling ships contaminated by fallout from our weapons testing. We apply the same criteria for special operations and return to the normal protection criteria as soon as the ship is recovered. This matter is well covered in the soon-to-be-issued Bureau of Ships Technical Manual, Chapter 90, entitled "Radiological Recovery of Ships After Nuclear Weapons Explosions." There is always a conflict between going slowly enough to assume a minimum exposure to the recovery team, and a proper haste to get the ship back in normal operations. One has to decide whether to go ahead now or wait for the activity to decay a bit. Except in war, however, the intentional exposure of personnel will not be permitted to overstep the accepted criteria for radiological safety.

The U.S. Naval Radiological Defense Laboratory has advocated that the Navy comply with all peacetime regulations relating to exposure to personnel and the deliberate release of radioactive materials to the public domain. However, it should not insist on complying with NCRP environmental criteria for those areas under its administrative jurisdiction (e.g., a ship). In all instances, of course, exposure is strictly controlled.

Attention is called to the fact that this scheme provides a basis for three levels of radioactive hazard environment, and three levels of decisions. A wide range of individual situations is covered by each level.

It is necessary, in some instances, to distinguish among three kinds of clearances based on three applications of radiation protection criteria:

(1) Operational clearance applies when contamination levels are high enough to demand special procedures and precautions.

(2) Standard clearance, specifying a level of radioactive contamination above that specified by NCRP environmental standards, but for which radiation and contamination control can be achieved by standard operation procedures. This condition is analogous to that obtained in restricted or controlled areas of nuclear industrial plants.

(*b*) *Application to program decisions.*—The definition of acceptable exposure, plus the graded decision procedure, permits the Government agencies to make plans with much greater assurance since the environmental state is directly linked to the quantity and the concentration of radioactive material. For example, one might define a weapon test program as within the realm of "normal programs," provided environmental testing:

(1) Is conducted at the PPG.
(2) Does not exceed a total of 1 MT/yr.
(3) Does not include any shots $>$100 KT.

Anything outside this limit would fall in the area of "special operations."

Projects such as ANP, Pluto, and Rover could proceed provided the total quantity, concentration and frequency of depositing radioactive material over specified areas did not exceed certain limits. Plans exceeding these limits become special operations and may require exceptional public health measures.

Projects such as Chariot become evaluated in the light of past, present, and future programs and the way they relate to the specific environmental areas involved.

Since a nuclear accident may be a major event, the total quantity of nuclear material which may be involved is an important consideration. Thus, a choice between two nuclear devices, one which is mechanically more reliable but releases more fission products into the atmosphere than another which has a higher failure probability may be involved.

(3) Final clearance, specifying a condition which complies with NCRP environmental limitation for unrestricted access.

(c) *Wartime criteria.*—Although wartime situations are not being considered in these hearings, serious radiological disaster conditions in peacetime can be handled more assuredly if compared with the thinking that has gone into planning for wartime operations. Under such circumstances, as discussed above under the emergency phases of nuclear accidents, dose-effect tables along with executive decisions as to the acceptable level of personal, acute injury are the ruling criteria.

A true safety picture demands that the radiation hazard be judged as a portion of the total picture. All aspects, such as personal hazard from nonradiological sources, radiation hazard to individuals involved, radiation hazard to the population if action is not taken, and the economic consequences of the alternative action must all be considered in the ultimate decision as to allowable radiation dose. It is, of course, highly desirable, under all conditions, to stay within the ICRP emergency limit of 12 rem; but situations threatening the health, safety, and welfare of the public may require that individuals be exposed to extreme hazards. This situation is not unique to radiological accidents.

The ultimate extension of this principle is seen in the wartime situation: The radiation risk is made subordinate to the accomplishment of the mission whenever the application of radiation protection compromises the mission. In this instance, the dose-effects tables will be used to predict casualties rather than to prevent them.

The choice would be influenced by the amounts of normally created radioactive materials. If the amounts correspond to the lower levels of environmental concern, the planners have a wide range of freedom for action. If they correspond to higher environmental levels, the degrees of freedom decrease.

The point is that the boundary conditions influencing the program can be seen while the plans are still on the drawing board. Engineers are very astute about designing themselves out of trouble once they see what the trouble is.

(e) *Application to hot spots.*—The Atomic Energy Commission has defined a "hot spot" relating to fallout as an area where the concentration of radioactive materials is some two or three times that of the surrounding territory. The U.S. Naval Radiological Defense Laboratory would define a "hot spot" as any area in which environmental measurements applying to free field measurements of gamma radiation or measurement of radioactivity in air, food, water, etc., would lead to average dose predictions greater than three times the annual rate based on background. The fundamental distinction between the AEC definition and the USNRDL definition is that we make no distinction as to origin of the material, but relate it to the average environmental levels. Such conditions can be reached either by spotty distribution of a massive deposition such as fallout over a wide area or could be reached by the accumulation of many sources in the growing nuclear industry.

(f) *Application to waste disposal.*—Regulations controlling present waste disposal for nuclear ships, etc., are based upon present levels permitted by the Federal Register. These permitted levels are fixed numbers applying equally to all parts of the environment and the way they are met is the responsibility of the using agency. Thus, each using agency must set up regulations of its own specifying the manner in which radioactive materials can be released in the open ocean, in the water offshore, and in harbors. Those prescribed by the Navy appear elsewhere in the testimony.

Since it is apparent that an acceptable combination of concentration, total amounts at one time, and annual release rates will vary widely between harbors, and even in different segments of the ocean, such an approach does not appear appropriate. It appears that such release conditions should not be fixed but should be adjustable and need not be the same from one harbor to the next. Use factors for the water concerned (including recreational, industrial, and similar features) should be taken into consideration. Provisions should also be made for special conditions for radioactive materials where certain elements can become highly concentrated, as was the case of cobalt in clams. Thus, it is the need of the environment that determines the level and rate of disposal, and this responsibility cannot be met by the using agency alone.

Extending this principle on a broader sense, present evidence indicates that the uptake of radioactive materials from sources such as fallout, varies with the time of year and offers opportunities for bypassing normal food chains. It is entirely conceivable that specifications of radioactive material release should be more liberal at one time of the year than at another provided the annual accumulation features are not violated. It is pointed out that the generation of regulations of this type are considered by many to be in the province of State and local jurisdiction rather than Federal. However, since many of the federally sponsored programs involving radioactive material released, particularly for military pur-

poses, are also involved, it is apparent that basic regulatory controls must emphasize the origin and method of operation and should deemphasize fixed limitations on environmental levels, per se. One of the consistent practical features of the impact of radioactivity on any new situation, is the way in which its influence cuts across customary lines of organization and responsibility.

No recommendation is made on how to handle this type of problem, but the reality of its existence should be recognized.

Appendix 5

Background on the Development of Basic Dose Recommendations

(Excerpt from preprint statement of Dr. G. Failla)

1. Evolution of permissible limits of exposure to ionizing radiation

Soon after the discovery of X-ray (1895) it became apparent that skin damage could be produced by exposure to this type of radiation. It was also realized that the damage extended to the deeper tissues and in fact it was this observation that led to the use of X-rays in the treatment of cancer. It did not take long to realize that any body tissue or organ could be damaged if the amount of radiation reaching it was sufficiently large. The existence of a "latent period," or delay between the exposure and the manifestation of the injury, was noted early, but this refers only to effects observable within a few weeks or a few months at the most, which may be referred to as the short-term effects of radiation. Obviously, the long-term effects of overexposure to radiation (e.g., the production of cancer) did not become apparent for a considerable time. It is now known that the interval between acute local overexposure and the appearance of cancer of the skin may be greater than 25 years, although in general it is about 10 to 15 years. In the case of occupational exposure, the dose accumulates slowly and the delay is even greater.

By 1920 many of the early radiologists and technicians had developed cancer of the skin (usually in the hands or face, because these parts received the largest doses) and others had died of anemia and probably leukemia. During the 1920's there was considerable activity in different countries to improve the protection of radiologists and technicians. In order to establish some norms, physical measurements of radiation exposure were made in many radiological installations. Since the roentgen as a unit of dose was not adopted internationally until 1928, the measurements were usually expressed in terms of the "acute" (single exposure) X-ray dose required to produce a reddening of the skin (the "erythema dose"). From these studies evolved the concept of a "tolerance dose" and the values suggested for it ranged from 0.002 to 0.01 of an erythema dose per month.

It is important to note the process by which these values were arrived at. The measurements mentioned above, established (albeit with rather low accuracy) the degree of occupational exposure of personnel in typical departments of radiology. This could be related to the state of health of those who had been exposed essentially at this rate for a number of years. By comparing the conditions of exposure with those to which certain workers had been subjected and had been or had not been injured, an estimate of a "safe" rate of exposure was made. The thinking at the time was that if no appreciable injury was evident within several years, it would be safe for the individual to be exposed at the same rate indefinitely. Skin damage was the main problem in those days and there was ample clinical experience to support the view that substantial recovery took place. Accordingly, it was expected that if the rate of exposure was low enough, tissue damage would be corrected by recovery and repair processes and no appreciable injury would result in the lifetime of the individual. It should be noted that repair of damage (e.g., the healing of a wound, the replacement of lost blood) is a normal physiological process and at the time it was reasonable to suppose that it applied to radiation damage as well. As a matter of fact, it does apply, but the difference is that after gross tissue repair has occurred there is still some residual damage—often imperceptible at first—which persists and may lead to serious complications many years later. Another important point to keep in mind is that the realization of the dangers of exposure to ionizing radiation was a gradual process and that at each step greater precautions were taken. Thus, at any particular time the exposure of personnel was less than it had been 10 or 15 years before and, therefore, the injuries seen then in the older radiologists had been produced under conditions that no longer existed.

The International X-ray and Radium Protection Commission, which later became the International Commission on Radiological Protection (ICRP), was established in 1928 by the Second International Congress of Radiology. This Commission recommended a "tolerance dose" of 0.2 r per day in 1934. The same value was recommended in this country by the Advisory Committee on X-ray and Radium Protection, which later became the National Committee on Radiation Protection (NCRP). Some time before 1920 I established the practice of taking monthly blood counts of all technicians working with radium in my laboratory, although by the nature of the work the chief hazard was injury of the skin of the hands. In 1927 I designed the first teletherapy apparatus with 4 grams of radium in which it was possible to "shut off" the gamma ray beam during the process of adjusting it to the patient. This device was operated 24 hours a day and three technicians in 8-hour shifts were in attendance. In the course of operating this device and watching the patient through a lead-glass window, these technicians were exposed to some radiation. The exposure was determined by film badges calibrated with radium gamma rays. Since blood counts were taken every month, a few years later (1932) it was possible to establish that this rate of exposure did not produce perceptible changes in the blood counts of two of the technicians [1] who had had the longest exposure, namely 4.5 and 3 years, respectively. (The third one had left earlier.) These physical measurements and blood counts provided the basis for a "radium protection chart" in which I related the amount of radium, the lead thickness of the shield, and the distance that would provide "adequate" protection. The chart was later included in HB 23 (1938). This development is recounted here because it provides the background for the adoption in 1936 of a tolerance dose of 0.1 r per day by the Advisory Committee on X-ray and Radium Protection, when the internationally recommended value was 0.2 r per day. By this time reasonable agreement had been reached on the measurement of radium gamma ray doses in terms of the roentgen, and it turned out that my "radium protection chart" (which in itself did not involve the dose) corresponded to a tolerance dose of very nearly 0.1 r per day. This value had the merit that it was based on actual experience indicating a lack of effect on blood count in two technicians who had been exposed for a few years. This could hardly be considered satisfactory evidence, but it was better than anything available at the time. Perhaps exposure at the rate of 0.2 r per day would not have produced any perceptible changes in blood count in the two technicians either, but the general feeling of lowering the tolerance dose was in the air and, at my suggestion, the committee adopted 0.1 r per day as the tolerance dose (HB 20 (1936)). I might add that at that time the genetic hazard of exposure to ionizing radiation was beginning to be recognized by nongeneticists, largely through the efforts of H. J. Muller, who was the leading expert in this field. Suggested values of the tolerance dose in chronological order are given in the appended table, reproduced from "Radiation Protection," by Braestrup and Wyckoff.

In the development of the atomic bomb great caution was exercised and all protective measures were designed to comply with the adopted maximum daily hose of 0.1 r. (While many individuals were involved in radiation protection, Dr. Robert Stone deserves the chief credit in that he set the pattern in the early days of the Plutonium project.) New problems had to be faced and even new units had to be coined. (Dr. H. M. Parker was largely responsible for introducing the "rep" and the "rem".)

After the war it became evident that the radiation protection problem had reached proportions undreamed of before. Accordingly the Advisory Committee on X-ray and Radium Protection was reorganized and became the National Committee on Radiation Protection, with a much larger membership and scope of activity. I became chairman of Subcommittee I, which was charged with the task of formulating basic rules. Dr. K. Z. Morgan was made chairman of Subcommittee II, dealing with the difficult problem of establishing permissible body burdens of radioisotopes and related matters. I invited two prominent geneticists (Dr. H. J. Muller and the late Dr. Donald R. Charles, later replaced by Dr. Curt Stern) to become members of Subcommittee I. This was the first time that any geneticist took a direct part in the deliberations of a radiation protection committee.

[1] Both are still alive.

TABLE I.—*Historical development of "tolerance dose"* [1]

Date	Author	Days for ½₁₀₀ erythema	Calculated r per day
1902	Rollins	(2)	10.00
1925	Mutscheller	3.0	.2
1925	Sievert	3.0	.2
1926	Solomon	.3	2.00
1927	Dutch Board	15.0	.04
1928	Barclay and Cox	3.5	.17
1928	Kaye	5.0	.12
1932	Failla (γ rays)	30.0	[3].1
1932	Stenstrom	3.7	.16
1934	ICRP [4]		.2
1936	NCRP [5]		.1
1949	NCRP		[6].05
1950	ICRP		[6].05

[1] Reproduced from "Radiation Protection," by Carl B. Braestrup and Harold O. Wyckoff; Charles C. Thomas, publisher.
[2] Photographic.
[3] Estimated from gamma-ray erythema = 1,800 r. Other calculations on erythema = 600 r.
[4] International Commission on Radiological Protection, then known as International X-ray and Radium Protection Commission.
[5] National Committee on Radiation Protection and Measurements, then known as Advisory Committee on X-ray and Radium Protection.
[6] Based on a weekly irradiation of 0.3 r in air.

The subcommittee realized at the outset that the development of the atomic bomb made necessary an entirely new approach to the protection problem. Before the war occupational exposure occurred largely in medical installations and one had to deal mostly with X-rays produced at voltages in the range of 80 to 250 kilovolts. Therefore, it was sufficient to express a "tolerance dose" in terms of roentgens per day without being too specific as to the region of the body to which this applied. In general in this country a measurement for protection purposes was made "in air," without the presence of the human body, at the place where the worker would be in the performance of his duties. The new sources that became available after the war provided radiation of different types and widely different penetrating powers. Also, radioactive material entering the body would go to some internal organs and would irradiate them even though the radiation they emitted was of very low penetrating power. These problems, of course, had to be faced during the war and the tolerance dose of 0.1 r per day (or its equivalent for nonelectromagnetic radiation) was made to apply to the dose delivered to any body tissue.

The subcommittee introduced the concept of "critical organs" and specified the harmful effects to be guarded against. The specified critical organs and effects (in parentheses) were: skin (cancer), blood-forming organs (leukemia), gonads (sterility), lenses of the eyes (cataracts). This refers primarily to exposure resulting from sources outside of the body. For "internal emitters" organs in which a radioactive material concentrates to a high degree, constitute critical organs also. In principle the "permissible dose" (see below) for each critica-organ should be chosen on the basis of the radiosensitivity of the organ with respect to the pertinent harmful effect, the seriousness of this effect and other considerations. There was not sufficient information at the time to do this quantil tatively for each critical organ and effect. Therefore, a distinction was made only between skin and the other critical tissues, in that the permissible dose for the skin was set at twice the value recommended for the other critical tissues. There was a sound basis for this because much more was known about long-term skin damage by radiologists and cancer of the skin is readily curable in most cases, while leukemia is always fatal.

Long-term experiments on animals carried out during the war indicated that there might be a shortening of life due to nonspecific causes, even at low levels of chronic exposure. Experiments and theoretical considerations indicated that genetic damage should be expected even from very low doses. For these reasons (and less tangible ones) the feeling had grown in previous years that the concept of a "tolerance dose" as a safe dose should be abandoned. To make the change perfectly clear the subcommittee decided to use a new expression—the permissible dose. The following statement from HB–59 defines and explains the new terminology.

"PERMISSIBLE DOSE

"The concept of a tolerance dose involves the assumption that if the dose is lower than a certain value—the threshold value—no injury results. Since it seems well established that there is no threshold dose for the production of gene mutations by radiation, it follows that strictly speaking there is no such thing as a tolerance dose when all possible effects of radiation on the individual and future generations are included. In connection with the protection problem the expression has been used in a more liberal sense, namely, to represent a dose that may be expected to produce only 'tolerable' deleterious effects, if any are produced at all. Since it is desirable to avoid this ambiguity the expression 'permissible dose' is much to be preferred.

"It is now necessary to give this expression a more precise meaning. In the first place it is well to state explicitly that the concept of a permissible dose envisages the possibility of radiation injury manifestable during the lifetime of the exposed individual or in subsequent generations. However, the probability of the occurrence of such injuries must be so low that the risk would be readily acceptable to the average individual. Permissible dose may then be defined as the dose of ionizing radiation that, in the light of present knowledge, is not lexpected to cause appreciable bodily injury to a person at any time during his ifetime. As used here "appreciable bodily injury" means any bodily injury or effect that the average person would regard as being objectionable and/or competent medical authorities would regard as being deleterious to the health and well being of the individual. 'Dose' is used here in its radiological sense and particularly as tissue dose in the irradiated tissue, organ, or region of interest. What constitutes the region of interest depends on the conditions of exposure and must be taken into account in assigning numerical values to the permissible dose or doses applicable to a given set of conditions."

The quotation is pertinent at this time because there seems to be considerable confusion as to the exact meaning of "maximum permissible dose." The word "permissible" is certainly appropriate in a legal sense. Thus, the speed limit posted on a road represents the maximum permissible speed, but there is no implication that if this speed is not exceeded there will be no traffic accidents on that road. Actually the change in terminology was made not because the new terminology was better than the former (as far as the words are concerned) but to get away from the concept of a dose that produced no damage, which people associated with the expression "tolerance dose." The change in terminology was intended to emphasize the change in concept. Many technical terms involve the use of common words that are given a special meaning by definition. The definition is what counts and not what the man in the street may think it means. (As an example, legal terminology is not always meaningful to the average individual.) The latest definition of permissible dose is given in section 2 below.

As mentioned before, when the "tolerance dose" of 0.1 r. per day was recommended, occupational exposure consisted largely of exposure to medium voltage X-rays. In the case of radiologists the exposure was mostly from fluoroscopes and the radiation traversed the body in the general direction of front to back, although scattered radiation could come from any direction. With the more powerful sources of radiation that came into use during and after the war, and the diversity of applications outside of the medical field, it became evident that the distribution of radiation in the human body could be much more uniform than it had been before. To take care of this situation, the subcommittee decided to assign to all critical organs except the skin, permissible doses that numerically were about one-half of the previous tolerance dose, that is 0.3 r. per week. The permissible dose for the skin was set at 0.6 r. per week (numerically the same as the previous tolerance dose in a period of 6 days). Actually a direct comparison cannot be made because the basis of measurement is different in the two cases: the tolerance dose was usually measured "in air," while the new permissible doses were expressed in terms of the doses received by specified organs. On the whole the new recommendations were intended to insure greater protection, but it is difficult to say by what factor.

The subcommittee changed the time basis from 1 day to a week ("7 consecutive days") for practical reasons. If the limit is for 1 day, then in order to be sure that it is not exceeded, the monitoring device (e.g., a film badge) must be read every day. This is wholly unnecessary when the working conditions are such that no large fluctuations of exposure occur from day to day.

The subcommittee introduced several other innovations, which need not be discussed here. One deserves brief mention because it marks the beginning of the

recommendations for a lower permissible dose for persons nonoccupationally exposed. The pertinent statement in HB–59 is as follows:

"Because it is impractical to keep account of the exposure of individuals outside an area in which occupational exposure occurs, it is necessary to make sure that the weekly dose received by minors outside said area be negligible insofar as subsequent occupational exposure is concerned. A factor of 10 is considered satisfactory for this purpose. Therefore, it is recommended that in cases in which minors may be exposed to radiation in the course of their normal activities, protective measures be taken to make sure that no minor actually receives radiation at a weekly rate higher than one-tenth the respective basic permissible weekly doses for the critical organs and other body tissues, according to the basic dose distribution."

All the recommendations made by the subcommittee were accepted by NCRP and were published as HB–59 in 1954. Actually agreement had been reached on most of the recommendations at the first meeting of the subcommittee in 1948. Informal reports were made by the Chairman of NCRP to other subcommittees and the new limits were used as a basis for their recommendations long before HB–59 was published.

In 1948 I went to England to discuss the proposed new permissible limits with the British counterpart of our NCRP. Our basic proposals were accepted. They were also accepted later by the International Commission on Radiological Protection. (Compare HB–59 and Recommendations of ICRP published in 1955 as Supplement No. 6 of British Journal of Radiology.)

While the genetic hazard was discussed by subcommittee I, no specific recommendations were made in HB–59. This was done (with the approval of the two geneticists on the subcommittee) simply because the handbook dealt with occupational exposure and the genetic effects of such exposure at the recommended limits on the whole population would be minimal. It was planned to prepare a second report dealing exclusively with the genetic problem. As chairman of the subcommittee I was about to arrange a meeting of the leading geneticists in this country to discuss the problem, when I heard that the National Academy of Sciences had been asked by the Rockefeller Foundation to study the biological effects of atomic radiations. The reports of this study were published in 1956 and an extensive discussion of genetic effects is included. A similar report was issued simultaneously by the British Medical Research Council. The problem was also discussed by the ICRP at its meeting in Geneva, April 1956, and a preliminary statement was issued later. More will be said later.

2. Latest recommendations of the International Commission on Radiological Protection

At the Geneva meeting of ICRP (April 1956) I proposed a further reduction in the permissible dose for occupational exposure of the whole body. The reasons are given in the Commission's report "Radiation Protection—Recommendations of the International Commission on Radiological Protection" published by Pergsmon Press. A brief summary will be given here.

It has always been emphasized by both NCRP and ICRP that the exposure of radiation workers should be kept as low as practicable, irrespective of maximum permissible limits. In general there has been very good cooperation on the part of responsible authorities in this respect and liberal factors of safety have been introduced in the design of radiation installations to reduce the actual exposure of workers much below permissible limits. Thus in AEC installations the great majority of workers received less than one-tenth the yearly permissible dose in 1955. However, the 1955 Conference on the Peaceful Uses of Atomic Energy aroused great interest in the development of atomic powerplants throughout the world. In time this would greatly increase the number of persons occupationally exposed and would also bring about actual or potential exposure of other persons and the population as a whole. More importantly, the pressure for producing power economically might well do away with the "safety factors" mentioned above. Also, the average duration of occupational exposure per individual worker might increase.

On the biological side, it appeared that perhaps "recovery" plays a less important part in the long-term effects of radiation to be expected from continued exposure at low levels than was earlier supposed. The higher than normal incidence of leukemia in radiologists had been well established. A statistical study by Dr. Shields Warren showed that the average age at death was about 5 years lower for radiologists than for other specialists, presumably not exposed to radiation in the exercise of their professions. (This was later found to be due largely to differences in the age distributions of the groups of specialists. A similar survey made in England recently shows no significant difference in longev-

ity between radiologists and other medical specialists. Nevertheless, the possibility of a certain degree of life shortening attributable to whole body exposure to penetrating radiation cannot be excluded.)

The ICRP recommended a reduction in the maximum permissible dose for whole body occupational exposure by approximately a factor of three. It retains essentially the former limits for (internal) exposure of single organs, except the gonads. In addition certain changes of practical importance were also made. As mentioned above, in AEC installations the actual dose received by the average worker was much less than the maximum permitted value. Although no similar information is available for other installations, this must also be true in general. However, certain operations, especially in cases of emergency, cannot be carried out at all—or at least economically—without exposing workers temporarily to higher levels of radiation. Therefore, the ICRP made provisions for higher temporary exposure levels ("within a period of 13 consecutive weeks") and adopted a formula first introduced by NCRP for the maximum occupational dose that could be accumulated up to a given age. For the most critical organs and whole body exposure the formula is $D=5\ (N-18)$ where D is the accumulated dose in rems at age N years, with the proviso that in any 13 consecutive weeks the dose should not exceed 3 rems. This means that while on the average the limit for occupational exposure corresponds to 5 rems per year, some workers who have not accumulated the maximum dose at their ages may receive up to 12 rems in one year. This takes care of practical requirements and at the same time insures that the accumulated dose at any given age does not exceed one-third the maximum value formerly permitted. It is important to note that in effect the new recommendations do not decrease the average dose actually received by radiation workers by a factor of three, because the average worker never received anything like the full quota. Therefore, the new recommendations do not impose undue restrictions, but limit the dose that could possibly be accumulated by an individual to one-third of its former value.

The definition of permissible dose in the latest report of ICRP is more explicit than that in HB 59. The pertinent paragraphs are quoted below:

"(29) Any departure from the environmental conditions in which man has evolved may entail a risk of deleterious effects. It is therefore assumed that long continued exposure to ionizing radiation additional to that due to natural radiation involves some risk. However, man cannot entirely dispense with the use of ionizing radiations, and therefore the problem in practice is to limit the radiation dose to that which involves a risk that is not unacceptable to the individual and to the population at large. This is called a permissible dose.

"(30) The permissible dose for an individual is that dose, accumulated over a long period of time or resulting from a single exposure, which, in the light of present knowledge, carries a negligible probability of severe somatic or genetic injuries; furthermore, it is such a dose that any effects that ensue more frequently are limited to those of a minor nature that would not be considered unacceptable by the exposed individual and by competent medical authorities.

"(31) Any severe somatic injuries (e.g., leukemia) that might result from exposure of individuals to the permissible dose would be limited to an exceedingly small fraction of the exposed group; effects such as shortening of lifespan, which might be expected to occur more frequently, would be very slight and would likely be hidden by normal biological variations. The permissible doses can therefore be expected to produce effects that could be detectable only by statistical methods applied to large groups."

It will be noted that since 1934 the maximum permissible level of continued whole body occupational exposure to ionizing radiation has been lowered in three steps from 60 to 5 rems per year. Each time the reduction has been made not because of definite knowledge of harm produced by exposure at the higher permissible limit, but because it was judged prudent to do so on the basis of radiological experience, animal experimentation and theoretical considerations. By 1934 there was a general awareness of the hazard, and gross short-term injuries were no longer common. It would have taken at least 25 years of exposure at the same level to evaluate the long-term effects and then only by statistical methods.

It is important to note in this connection the difference between a maximum permissible limit and the average dose that workers actually receive. Both NCRP and ICRP have always emphasized that the exposure should be kept as low as practicable. Designers of radiation installations have taken this seriously and have used substantial factors of safety, at least during the last 20 years. For this reason, compliance with the lower permissible limits in general has not neces-

sitated marked changes in protective barriers or operative procedures. To a certain extent this accounts for the ready acceptance of lower permissible limits. However, considerable resistance to further reductions is to be expected.

Maximum permissible limits for occupational exposure apply to the individual employee. In other words, the intent is to protect each employee. This means that the employer must provide protective devices and procedures to make sure that no individual in his employ receives a dose in excess of the maximum permissible limit. To do this he is forced to use an administrative limit lower than the permissible maximum. (The ratio of the two constitutes the "safety factor" mentioned above.) In practice it is found that in large installations only a small percentage of those occupationally exposed to radiation receive doses approaching the maximum permissible values. The average dose is usually much lower.

In this connection it is well to point out that it would not be proper to set limits of occupational exposure in terms of the dose received by the average employee. In a plant with a large number of employees, some could receive really large doses, while maintaining the required low average.

It should be noted that changes in permissible limits of exposure made during the past 30 years have resulted in a decrease of accumulated dose, but also in an increase in the single dose that a person could receive. When the limit was 0.1 r. per day, the single dose, that is, the dose received in one exposure, could not exceed 0.1 r. When the limit was 0.3 r. per week, the single dose could not exceed 0.3 r. Now the dose reckoning period has been stretched to 13 weeks and the maximum permissible single dose is 3 r. This has been done to meet practical requirements. It is unlikely that further increases will be allowed until much more knowledge of the biological effects of ionizing radiation is acquired.

3. Permissible limits for nonoccupational exposure

As already mentioned the first attempt to regulate exposure of persons outside of radiation installations was made in HB–59. This was done indirectly (see quotation in the previous section) by stipulating that children should not be exposed at a rate higher than one-tenth the maximum permissible weekly doses for occupational exposure. Note that the ostensible reason for this was to make sure that the dose received by children up to the time (18 years) that they might be employed in a radiation installation would be negligible in comparison to the occupational exposure they would receive in a lifetime. Taking this as a basis, the ICRP report published in 1955 contained the following statement: "The Commission recommends that, in the case of the prolonged exposure of a large population, the maximum permissible levels should be reduced by a factor of 10 below those accepted for occupational exposures." Actually this came about through some misunderstanding, since the factor of one-tenth was never intended to apply to a large population. There has always been considerable reluctance on the part of radiation protection groups to make recommendations for the exposure of large populations: in the first place because of the limited knowledge concerning the effects of exposure at low levels of ionizing radiation; and secondly because the problem might well be considered to be outside the scope of their activities. Nevertheless, by the time that the ICRP held its meeting in Geneva in 1956, it was evident that something had to be done.

Geneticists (and others) have emphasized the genetic hazard for a long time and have recommended that exposure of the gonads be limited "as much as possible." This sort of recommendation is of no use to engineers designing nuclear powerplants or, for that matter, designing the protective shields and devices for any source of radiation. It is always "possible" to reduce the exposure if one is willing to pay the price. At what point should the engineer stop? On the other hand, lack of knowledge made everybody reluctant to set a permissible limit for the genetic dose to the whole population in numerical terms. The Genetics Committee of the National Academy of Sciences deserves the credit for resolving the impasse, by recommending that the "general population shall not receive from such sources (manmade sources) an average of more than 10 roentgens, in addition to background, of ionizing radiation as a total accumulated dose to the reproductive cells from conception to age 30." The British group made no specific numerical recommendation but indicated the order of magnitude and suggested that ICRP should set the value.

The preliminary recommendations made by ICRP in 1956 were couched in general terms but in the 1959 report they are very specific. It accepted the genetic dose of 10 r. suggested by the NAS Genetics Committee as an upper

limit and suggested a subdivision of this total into allotments for specific purposes, as follows:

	Rems
Medical exposure	5. 0
Occupational exposure	1. 0
Exposure of special groups	. 5
Exposure of the population at large	2. 0
Reserves	1. 5

It is important to note that the ICRP does not recommend that the genetic dose from medical exposure be 5 rems. In fact it recommends "that it be kept as low as is consistent with the necessary requirements of modern medical practice." It simply recognizes the fact that the estimated genetic dose in some countries is close to 5 rems. The quotas for nonmedical exposure are ample to permit foreseeable expansion of the peaceful uses of atomic energy without undue restrictions.

The genetic dose to a population is the dose which, if it were received by each person from conception to the mean age of childbearing, would result in the same genetic burden to the whole population as do the actual doses received by the individuals. A permissible genetic dose is that dose which, if it were received by each person from conception to the mean age of childbearing, would result in an acceptable burden to the whole population. In order to evaluate the genetic dose one must know the relation between dose and genetic effect. It is generally assumed that the relation is a linear one, that is, that the genetic effect is proportional to the dose and that there is no dose (no threshold dose) below which no genetic effect is produced. On this basis a large dose to a few individuals is equivalent to a small dose to a correspondingly larger number of individuals, insofar as the genetic effect on the total group of individuals is concerned.[3] There is a good scientific basis for this assumption, although the recent work of Dr. William L. Russell and his staff at Oak Ridge indicates that some modifications may have to be made.

In the case of somatic effects there is considerable difference of opinion as to the dose-effect relationship and in particular as to the existence of a threshold dose for any given effect. Obviously, if there is a threshold dose, those receiving lower doses would show no effect at all. If there is a threshold dose and its magnitude is higher than any dose that could be accumulated at permissible levels of occupational exposure, there is no reason to have lower permissible limits for nonoccupational exposure as regards somatic effects. The matter is only of academic interest insofar as setting a limit to the population dose resulting from external sources of penetrating radiation is concerned. Under these conditions genetic damage is of paramount importance and the limitation of the dose to the gonads will automatically limit the dose to the rest of the body to essentially the same level. The top limit recommended by the ICRP for the genetic dose from all manmade sources (except medical exposure) is 5 rems. Therefore, this will indirectly limit the whole body dose to 5 rems in 30 years or 12.5 rems in 75 years. This is certainly satisfactory for the present time because the actual whole-body dose of penetrating radiation received by the population from manmade sources is certainly much less than this and it can only increase very slowly. Obviously, the rate of increase must be under control if the genetic dose must never reach the 5-rem limit. The ICRP (and NCRP as well) has always reserved the right to change the recommended permissible limits whenever new knowledge indicates that they should be changed.

The same limitation to the level of the genetic dose applies also to internal exposure resulting from radioisotopes that directly or indirectly contribute to the gonad dose or constitute whole-body exposure.

4. Permissible limits for radioisotopes that concentrate in a single organ

There is still considerable confusion as to the meaning of the ICRP recommendations for this case. The difficulty arises largely from the fact that some recommendations are made in terms of MPC and that the word "average" is not explicitly defined. For occupational exposure the permissible limit applies to any exposed individual and not to the average person in a group of radiation workers. However, an average dose with respect to time is involved here because the limit is set in terms of a certain dose in a certain period of time (e.g. 3 rems in 13 consecutive weeks) irrespective of the rate at which the dose is received.

In the case of exposure of a population, genetic and somatic effects are considered separately. The limit on the genetic dose is set from the point of view

[3] Note that the criterion here is the effect on a population, not the effect on any particular individual.

of protecting the descendants of the population (not the descendants of an individual member of the population). Therefore, the specified dose is the average for the whole population. On the assumption (which now is not quite valid) that genetic damage depends on the total dose accumulated by the parents up to the time of conception of a child, the permissible dose is stated in terms of the first 30 years of life, which is approximately the average age of parents at which offspring are conceived. (Note that this is another kind of "average".) The descendants of the individual are protected indirectly by the limit set for the permissible individual dose to the gonads, as critical organs, to guard against somatic effects.

For obvious practical reasons protection of the individual or the population from the hazards of internally accumulated radioactive materials is based on the control of the concentrations of these materials in air, water, food, etc. taken into the body. However, the reference point is the permissible tissue dose in a critical organ—which may be derived from the recommendations for exposure to external sources, or from the permissible body burden of Ra^{226} (0.1 microgram, for occupational exposure). The latter has the merit that it is based on actual human data, but it introduces difficulties in the calculation of the significant tissue dose responsible for the production of bone tumors and its equivalent for a different radioisotope. At any rate the starting point is the tissue dose in a given organ. Then calculations are made to determine the concentration of the material in air or water that would prevent the accumulation of a radiation dose in the organ in excess of the assumed maximum permissible value during the lifetime of the individual. The calculation involves many biological factors, most of which are not accurately known, but, even if they were, the values used would have to be averages, because of the considerable physiological differences among the members of a human population. In practice a fictitious "standard man" is set up with a certain total weight and weight of each organ, breathing air and drinking water at certain rates, dealing with each radioisotope (as an element or a compound) in a certain way, etc. Accordingly, the calculated maximum permissible concentration (MPC) applies to this standard man, which is intended to represent the average radiation worker. We have here another "average." Its significance should be kept in mind. Starting with a given tissue dose we calculate an MPC. Maintaining this MPC for the length of time originally assumed, we may expect that the tissue dose in the organ in question in the average radiation worker ("standard man") will reach the value originally assumed. However, the organ dose in some individuals will be lower and in some higher, because the concentration of radioactive material in the organ will be different owing to metabolic differences. In addition the biological effect of the same dose is different in different individuals. Hence greater differences in biological effect from one individual to another must be expected when the exposure is controlled by maintaining a certain MPC than when it is controlled by maintaining a certain radiation level—which can be done readily in the case of external exposure, but only in certain instances (e.g. radioiodine in the thyroid) in the case of internal exposure.

The foregoing discussion is pertinent to paragraph 68 of the 1958 ICRP report, which reads as follows:

"(68) There remain for further consideration those isotopes that concentrate in specific organs (other than the gonads). In view of the existing uncertainty as to the dose-effect relationships for somatic effects, it is suggested that for planning purposes the average concentrations of such isotopes, or mixtures thereof, in air or water, applicable to the population at large, should not exceed one-thirtieth of the MPC values for continuous occupational exposure given in the report of Committee II."

The question is how to apply the suggestions of paragraph (68) to the practical situation in which radioactive material is discharged into the air. The discharge may occur at intervals and may differ in amount. As in the case of intermittent exposure to external radiation, it is proper to base the permissible limit on an average concentration over a period of time. However, the concentration varies also from point to point in the surrounding area, depending not only on distance from the point of discharge but on wind direction and velocity and other factors. As a practical necessity some averaging with respect to area—or more appropriately with respect to population in the surrounding area—is indicated. Obviously, by choosing a large enough area the average dose to the occupants can be made very low, but then some individuals might well receive very large doses. This difficulty can be overcome by specifying two limits: one for the dose that any individual can receive and one for the average does to the population.

This matter was discussed at the Munich meeting of the ICRP in July 1959 and the following statements were issued:

"Additional section regarding exposure of individual members of the population at large (to follow after par. 57): A new section, under the heading 'Exposure of population at large' should be added after the section headed "Exposure of special groups" (par. 53–57). The text to be added, referring to both external and internal exposure, reads: 'The maximum total dose limit for individuals in the population at large (excluding those occupationally exposed and the special groups B(a) and B(b) should be that recommended for members of the special group B(c) (cf. par. 55).'

"Interpretation of paragraph 68: The basis for the limits of permissible exposure of populations to manmade sources of ionizing radiations is the dose received by the various organs of the body and not the MPC-values, or other criteria by which the dose is controlled. Nevertheless, for planning purposes some guidance as given in paragraph 68 must be available. The word 'average' in paragraph 68 refers to the concentration of radioactive nuclides, averaged over a year, in the total intake to the average person of the population."

Unfortunately the situation is still not very clear as to recommended values. The word "average" in paragraph (68) applies to concentrations of radioisotopes, but in the "interpretation of paragraph 68," it applies to the concentration in the total intake to the average person of the population. Having taken part in the discussions at Munich, I am sure the intent was to permit averaging of the "concentration" in a populated area. The magnitude of the area or population was not stated and is irrelevant because at the same time the ICRP set the maximum total dose limit for individuals in the population at large. (See "Additional section regarding etc." quoted above.) Unfortunately the reference to the dose recommended for special group B(c) paragraph (55) causes some uncertainty. The dose is 0.5 rem per year but it refers to the gonads, the blood-forming organs and the lenses of the eyes. Nothing is said about other organs. If it is assumed that it is intended to make it apply to other organs as well, we end up with the same value (0.5 rem per year) for the maximum permissible dose for an individual in the general population and for the average dose to the population as a whole. This comes about when the recommendation of paragraph (68) in terms of MPC is converted back to rems per year, that is, $\frac{1}{30} \times 15 = 0.5$ rem per year, (the basis being 15 rems per year as the maximum permissible tissue dose in a single organ, under the conditions of occupational exposure). In the case of isotopes for which the MPC's are based on the permissible body burden of Ra^{226} the situation is even more inconsistent in that the average dose to the population turns out to be higher than the maximum dose to the individual. The difficulty might be resolved by noting that paragraph (56) refers to "any single organ" rather than "the gonads, the blood-forming organs, and the lenses of the eyes" to which paragraph (55) refers. In this case the maximum permissible dose in a single organ for the individual in the general population would be 1.5 rem per year, when the MPC's are based on the occupational dose limit of 15 rems per year.

4. Will there be future reductions in permissible limits?

No definite answer to this question can be given at this time. The situation could be altered materially by new knowledge. To give an extreme example, it may become possible to raise, rather than to lower, the limits without increasing the hazards, if some way of counteracting the effects of radiation could be found. This is a big "if." The problem is of essentially the same magnitude as the cancer problem, to which it is related in the sense that both require vastly more knowledge of biological phenomena than is available at present.

Insofar as occupational exposure is concerned there has not been great opposition to the lowering of permissible limits because up to this time the increase in cost has not been very large. The general awareness of radiation hazards has put pressure on tne employers to accept lower limits. The exposure records of AEC installations have shown that most operations can be conducted with exposures substantially below permissible limits. Depending on circumstances, it may be justifiable to lower some limits to some extent, but I doubt that there can be a drastic overall reduction.

In regard to radiation exposure of the population the situation is more uncertain and much more is at stake. I should like to point out that it is rather simple to protect the population from stationary sources of radiation. These sources must be shielded anyway to protect the worker. The additional shielding required to lowder the dose rate to the value recommended for the population does not add significantly to the cost. I can give a concrete example since I have just designed a shield for a strong cesium 137 source. The lead shield required to permit

workers to stay close to the source is about 8 inches thick. The dose rate at any given distance from the source can be reduced to 50 percent by adding roughly one-fourth inch of lead to the shield. Another one-fourth inch of lead will reduce it to 25 percent, etc. This represents a small increase in cost in a shield that has to be 8 inches thick to begin with. Furthermore, the population is generally at a much greater distance from the source than the radiation worker and this in itself reduces the dose rate greatly.

A real problem is presented when one envisages the wide distribution of unshielded or lightly shielded gamma ray sources. In the past only watches and clocks with radium-luminous dials came into this category and the contribution to the population dose has been very small. However, the desirability of incorporating radioactive materials in articles of commerce, for one purpose or another, is increasing and rigid control of such use is essential to prevent a substantial increase in background radiation. At some future time the question may come up in acute form if the widespread use of a radioactive material would result in an important economic benefit. As an example I might suggest a hypothetical case. Assume that the efficiency of the automobile engine could be doubled by using spark plugs with a considerable amount of cobalt 60 in them. This is extremely improbable but if it could be done, it would be of tremendous economic value. There would then be great pressure to get approval of this use of cobalt 60, which might well increase the exposure of the population beyond the presently accepted limit of the genetic dose. Obviously in that case, the weighing of benefits against genetic damage would have to be done with much greater care than is necessary at the present time, and possibly the permissible limit would be raised. Incidentally, this is a good example of a function that only the newly created Federal Radiation Council could perform.

In the foregoing I have pointed out that in the case of stationary sources of radiation, the additional shielding required to reduce the dose rate to the value applicable to the population as a whole is relatively small. Difficulties may be encountered if the large scale distribution of unshielded gamma ray sources should become economically desirable. The problem does not seem very pressing at the moment. However, we have discussed only exposure of the population to external radiation. The matter of cost is much more important when it comes to internal emitters. A simple example will make this clear. Suppose that in an atomic energy plant radioactive material in gaseous form is discharged into the atmosphere. In order to reduce the concentration of the radioactive gas sufficiently to insure that the dose to the surrounding population does not exceed the permissible limit, a certain number of cubic feet of air per minute must be pumped into the stack. If now it is desired to reduce the concentration to 50 percent of the former value, twice as much air must be pumped into the stack at approximately twice the cost. Reduction of the concentration by a large factor may well bring the cost to an impossible level. Thus the practical utilization of atomic power will demand a closer look at MPC's for the general population. Again the question of balancing benefits against damage will come up—and much more scientific information than is now available will be needed to reach an equitable decision. The matter is one of national policy and should be adjudicated by the Federal Radiation Council.

5. Research needs

The spectacular success of the Manhattan project during the war has had the unfortunate effect of creating the impression in the public's mind that any problem can be solved quickly if sufficient funds are made available. Scientists know that this is true only in very special cases in which the basic knowledge for the solution of the problem is already at hand. As alluded to above, the cancer problem and the radiation hazard problem are not in this category. This refers specifically to the ideal solution of the radiation hazard problem, that is, to the finding of means to annul, counteract, or otherwise prevent the deleterious effects of ionizing radiation. The more immediate problem is to appraise the hazard in quantitative terms. Unfortunately even this much simpler problem cannot be solved quickly for the simple reason that the effects of chief concern require a long time to become evident. Obviously genetic damage must be studied in many subsequent generations. The shortening of life requires observation during one generation and preferably in subsequent generations as well, according to some observations made by W. L. Russell on mice. For obvious reasons experiments must be carried out on animals, preferably mammals including long-lived species. The range of doses or dose rates used must include some in the neighborhood of permissible limits. Since the injuries of chief concern in the protection problem (e.g., leukemia and bone cancer) occur spontaneously, statistically signifi-

cant results at low doses can be obtained only by using very large numbers of animals. In the end there is always the question of applying the results to man.

The foregoing refers to the empirical approach to the problem. In time enough information could be obtained in this way to make reasonable estimates applicable to man. Another, and inherently more fruitful approach in the long run, is to study the mechanisms of the biological actions of radiation from which generalizations can be derived. This also requires time because progress will depend on the elucidation of biological phenomena in general.

A third approach is to study human groups that for one reason or another have been exposed to fairly high radiation levels in the past. Some of this has been done already and other projects are underway. There is a tendency at the moment to undertake large-scale surveys of this sort in the hope that large numbers will provide significant results. Unless the epidemiological aspects of the study are carefully considered, there is danger that a great deal of money—and what is still more important, scientific manpower—will be wasted. Radioactive fallout offers an opportunity to do prospective studies of this sort, especially as regards the effects of internal emitters. However, great care must be exercised in deciding what should be done along these lines, to avoid unnecessary effort and expense that the current popularity of the subject may induce.

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Appendix 6

The Radium 226 Standard for Bone Seekers

(Preprint statement of Robley D. Evans and Robert A. Dudley)

The radium 226 standard, namely 0.1 microgram of radium 226 retained in the human skeleton, is based on direct observations on human beings. As a directly measured value, it involves no assumptions whatsoever concerning RBE, nonuniform distribution, retention, nor species ratios.

The radium 226 standard is therefore the basic or primary standard for the chronic effects on humans of bone-seeking radionuclides. There are no comparable data on the biological effects on humans of any other internal emitter. The presumed chronic effects on humans of strontium 90, plutonium 239, and other bone-seekers can be based on estimates of their effectiveness relative to radium 226. Such estimates can be made either experimentally—by measuring their relative chronic effectiveness in experimental animals such as the beagle dog, or theoretically—by calculating a presumed equivalent radiation dose. In such a calculation estimates are required of the effects of RBE, nonuniform distribution, and retention pattern in case these parameters have different values for radium 226 and for the bone seeker in question, say strontium 90.

The present experimental basis of the radium 226 standard of 0.1 microgram includes the following observations. Detailed medical, radiographic, and physical studies have been made in several research laboratories on a total of about 500 persons who have carried various amounts of radium or radium plus mesothorium in their bones for approximately 35 years. These persons, if living, are now mostly between 50 and 70 years of age. If their present radium burden, or pure radium equivalent (PRE) burden when mesothorium is involved, is 0.1 microgram of radium 226 or less, there is no case in which any significant symptom or sign of a possible radiation effect is observed.

In contrast, if the residual radium burden, some 35 years after its acquisition, is about tenfold greater, that is about 1.0 microgram or greater, then some individuals do have symptoms and signs which seem clearly attributable to the chronic radiation insult to which their bones have been subjected. These symptoms include discomfort due to necrosis and bone destruction especially in joints, pathological fractures, bone tumors, and tumors of the paranasal or the mastoid sinuses. The signs, or conditions which are not apparent to the person but which are demonstrable by radiography or other laboratory procedures, include occasional coarsening of trabeculation, osteoporosis, aseptic necrosis, and changes in the density or structure of individual haversian systems in the bone as seen by microradiographic examination of bone samples. No anemia, leukemia, or other blood dyscrasia has been demonstrated in the chronic radium and mesothorium cases which have been examined 10 to 48 years after exposure at MIT (about 250 of the 500 cases), even though the residual body burdens have been as high as 23 micrograms of radium.

In general the incidence and the severity of the symptoms and signs increases with increasing residual body burden above about 1.0 microgram. In the domain between about 0.5 and 1.0 microgram there are a few instances of symptoms of injury, but the domain from 0.1 to about 0.5 microgram appears to involve no unequivocal case with symptoms attributable to radiation.

In general, symptoms occur at burdens which are appreciably higher than those at which minimal signs can be detected by present techniques.

The radium 226 standard includes a large safety factor and is a conservative standard for individuals. The largest contribution to the safety factor arises from the time of application of the standard relative to the time of exposure. In applying the radium 226 standard to the protection of individuals it is customary to require that the permissible body burden never exceed 0.1 microgram of radium 226 or its equivalent of some other boneseeker. This is very much more conservative than requiring that some 35 years after termination of the exposure, the residual body burden should not exceed the equivalent of 0.1 microgram of radium 226. Yet the standard is based on measurements of the residual burden, not the initial burden, nor the maximum burden reached over an extended period of exposure. The curve of radium retention versus time in the human is not unequivocally established, but the power-function relationship, $1/t^{0.52}$, where t is the time in days, proposed by Norris, Speckman, and Gustafson in 1955 is commonly used. Then 0.1 microgram at 35 years corresponds to the residual retention of an earlier burden of 0.6 microgram at 1 year after exposure, or 2.3 micrograms at 1 month after an acute exposure. Thus, when the 0.1 microgram standard is applied with respect to initial burdens, rather than terminal burdens, a safety factor of the order of a factor of 20 or more is probably involved. If it were also presumed that the 0.1 microgram value is unrealistically low, and that symptoms of radiation injury will continue to be observed only with 35-year residual burdens of about 0.5 microgram or more, then the overall safety factor in the radium 226 standard might be as large as a factor of 100 when the standard is applied to initial or maximum burdens, rather than to terminal burdens.

The *average* skeletal radiation dose rate due to 0.1 microgram of radium 226 in 7,000 grams of bone is about 0.010 rad/day or 3.7 rads/year. If this 0.1 microgram is the residue 35 years after exposure, and the retention had been proportional to $1/t^{0.52}$ as discussed earlier, then the average skeletal radiation dose accumulated over the 35-year period can be shown to be about 190 rads. This corresponds to a dose rate of $(2.3/0.1)\times 0.010 = 0.230$ rad/day at 1 month after exposure $(0.6/0.1)\times 0.010 = 0.060$ rad/day 1 year after exposure, 0.010 rad/day 35 years after exposure, and a mean dose rate of $190/35 = 5.4$ rads/year averaged over the 35-year interval. These are *average* dose rates, and the "hotspots" or areas of greatest deposition in the bone will have experienced much larger doses, perhaps by a factor of 10 to 100. When this effect of nonuniform distribution, and the effect of the RBE of alpha radiation is taken into account, the local hotspot doses, which apply to only about 1 percent of the total bone, or 70 grams, and which produce no detectable effect in humans, are considerably larger than the conventional 0.3 rem/week or 15 rems/year of the so-called MPD for partial body, or 5 rems/year for whole body exposure. The MPD is, however, based on an entirely different concept, namely, that of protecting against genetic effects, shortening of life span, etc., which may be caused by a dose of external radiation to which the *whole body* is uniformly exposed. The MPD concept is thus not directly applicable to the local irradiation of small volumes of nongenetic skeletal tissue by bone-seeking radionuclides. At best the MPD is an indirect, independent, order-of-magnitude estimate for bone seekers which is entirely unrelated to the experimentally determined radium 226 standard.

The major area in which knowledge is lacking is that of the effect versus dose relationship. Although no symptoms or signs have been observed in humans with less than about 0.5 to 0.1 microgram of radium about 35 years after exposure, the 500 cases studied so far are quite insufficient to establish whether the effect versus dose relationship for these exposures has a true threshold, or is quadratic, linear, or log-normal. When the radium 226 standard is applied to 100 million people, rather than to a few thousand, the shape of the response curve at low doses is obviously very important.

It is hoped that some enlightment will be obtained from each of three approaches: (1) Continuing observations on as many human cases as can be located in the irreplaceable and limited reservoir for the direct study of changes produced by chronic radiation in humans, (2) measurements now in progress on dogs and other experimental animals, and (3) theoretical and experimental studies of fundamental radiobiological mechanisms.

APPENDIX 7

GLOSSARY

Alpha particle (α particle) — Helium nucleus; i.e., a close combination of two neutrons and two protons, and therefore positively charged. Alpha particles are emitted from the nuclei of certain radioactive elements.

Average dose — The arithmetic mean radiation dose. The average may be taken with respect to time, number of people, location, etc.

Background radiation — Radiation which is extraneous to that originating from a particular source under study. The term also is sometimes used to denote radiation from naturally occurring sources. (*See* Natural background radiation.)

Beta particle (β particle) — Swiftly moving electrons or positrons, and therefore negatively or positively charged respectively, when emitted by radioactive substances.

Biological model — A mathematical expression or other scheme which is devised to represent the functioning and interrelationship of biological processes.

Body burden — The amount of a specified radioactive material or the summation of the amounts of various radioactive materials in a person's body at the time of interest. The context usually clarifies which meaning is intended. (*See* Maximum permissible body burden, Organ burden.)

Controlled area — A defined area in which the occupational exposure of personnel to radiation or to radioactive material is under the supervision of an individual in charge of radiation protection. (This implies that a controlled area is one that requires control of access, occupancy, and working conditions for radiation protection purposes.)

Critical organ — An organ or tissue most affected by ionizing radiations from the deposition of a specified internal emitter or from external sources. The essentiality of the organ and its sensitivity to ionizing radiations are considered in determining the critical organ.

Curie, the (c.) — Measure of the activity (rate of disintegration or decay) of a radioactive substance. More specifically, that quantity of a radioactive nuclide decaying at a rate of 3.7×10^{10} atoms per second or 2.2×10^{12} atoms per minute.

Millicurie (mc.) — One-thousandth of a curie.

Microcurie (μc.) — One-millionth of a curie.

Micromicrocurie ($\mu\mu$c.) — One-millionth of a microcurie, or one-million millionth of a curie.

Megacurie (Mc.) — One million curies.

GLOSSARY—Continued

Dose	The dictionary definition is not appropriate in radiation protection. Definitive practice requires that the term be used in such combining forms as radiation dose, absorbed dose, whole body dose, partial body dose, etc. Where the context has established the specific meaning intended, it is common practice to use the term "dose" without repeating the modifier. Comprehensive discussion of the use of the term "dose" is contained in such reference documents as MDDC–1100 and CRUSP–1.[1] (*See* Radiation dose.)
Dose-effect relationship	The magnitude of a specific biological effect, expressed as a function of the radiation dose producing it. It is frequently represented as a curve described as a dose-effect curve, dose-effect response curve, or dose response curve.
Dosimeter	Any of several devices used for measuring dose and dose rate from various ionizing radiations.
Exposure	Often used in the sense of being made subject to the action of radiation.
Accidental	Unplanned, unintended exposure to ionizing radiations.
Emergency	A short-term, planned exposure to ionizing radiations in excess of long-term maximum permissible limits as a result of unusual circumstances.
Environmental	Exposure to natural and artificially produced sources of ionizing radiation beyond the boundaries of the controlled area.
External	The exposure of body tissues to ionizing radiations originating from sources outside the body.
Internal	The exposure of body tissues to ionizing radiations originating from radionuclides contained within the body. (*See* Internal emitters.)
Localized	The exposure to ionizing radiations of a small fraction of the whole body.
Medical	Exposure to ionizing radiations for therapeutic or diagnostic purposes; broadly, the purposeful exposure of patients by practitioners of the healing arts.
Nonoccupational	Exposure of individuals to ionizing radiations outside of controlled areas and exclusive of medical exposure.
Occupational	Exposure of an individual to ionizing radiations by reason of his work.
Whole Body	Literally, the exposure of the whole body.
Gamma rays (γ rays)	Electromagnetic waves of very short wavelengths produced during the disintegration of radioactive elements.
Half-life	The time taken for the activity—or for the total number of atoms—of a radioactive nuclide to decay or disintegrate to one-half of the initial value.

[1] Cantril, S. T., and Parker, H. M. "The Tolerance Dose," MDDC–1100. Argonne National Laboratory, Jan. 5, 1945.
Parker, H. M. "Some Background Information on the Development of Dose Units," CRUSP–1. American College of Radiology. November 1955.

GLOSSARY—Continued

Half-life—Continued	
Biological half-life	By analogy, the time taken for the total number of atoms of a nuclide to be reduced to one-half of the initial value by biological removal processes (of the body). Radioactive decay is not involved.
Effective half-life	By analogy and combination, the time taken for the total number of atoms of a radioactive nuclide to be reduced to one-half of the initial value by combined radioactive decay and biological removal processes from the body.
Average life or mean life	A particular atom can decay now, later, or never. The average or mean life expectancy of a number of the same radionuclides is a definite quantity, however, and is equal to 1.4 times the half-life.
Isotopes	Atoms of the same element, i.e., having the same atomic number, but of differing atomic weight are called isotopes of that element. The isotopes of an element are almost identical in chemical properties, and in all physical properties except those determined by the mass of the atom. The different isotopes of an element contain different numbers of neutrons in their nuclei. Nearly all elements found in nature are mixtures of several isotopes.
Internal emitters	Radionuclides contained within the body.
Ion	An atom or aggregate of atoms, which is not electrically neutral, viz, negative ion, positive ion. In certain circumstances an electron may be described as a "negative ion."
Natural background radiation	Ionizing radiations from naturally occurring radionuclides as they exist in nature plus cosmic radiation.
Neutron	An uncharged nuclear particle of approximately the same mass as a proton.
Fast neutron	A neutron having an energy between 10 Kev. and 10 Mev.
Slow neutron	A neutron of low energy. The upper limit of energy is often taken as 1 ev.
Thermal neutron	A neutron in termal equilibrium with its surroundings. At 15° C., the mean energy is about 0.025 ev.
Nuclide	An atom of a particular species; that is, characterized by an atomic number and an atomic weight.
NOTE.—$_{92}U^{235}$ is a nuclide. Uranium as it occurs naturally consists primarily of two nuclides, $_{92}U^{235}$ and $_{92}U^{238}$, which together bear the relationship of isotopes.	
Organ burden	The quantity of a radionuclide in a particular organ or tissue at the time of interest. (See Body burden.)
Organ dose	The radiation dose received by a particular body organ or tissue. The radiation may be from an external or internal source.
Per-capita dose	The population dose divided by the number of individuals in the population.
Population dose	The radiation dose received by members of a population.
Proton	A nuclear particle of unit mass number having a charge equal and opposite to that of an electron and having a mass of 1.672×10^{-24} gram. The nucleus of the lightest hydrogen isotope is a proton.

GLOSSARY—Continued

Radiation (ionizing)	Radiation capable of producing ions in a medium. Examples are X- and gamma rays, alpha and beta radiation, and cosmic radiations are examples of ionizing radiation.
Rad	The unit of absorbed dose (of radiation) in matter, equal to 100 ergs per gram. A measure of the energy imparted to matter by the ionizing radiation per unit mass of the irradiated material.
Rep	An older unit, now replaced by the rad. Equal to 93 ergs per gram of tissue.
Rem	That quantity of any type of ionizing radiation which, when absorbed in the human body, produces an effect equivalent to the absorption of 1 roentgen of X- or gamma radiation at a given energy.
Roentgen, the (r.)	That quantity of X- or gamma radiation required to produce in dry air (1 cc.) ions carrying 1 electrostatic unit of positive or negative charge.

NOTE.—The absorbed dose (in tissue) expressed in rad, multiplied by the RBE (q.v.) for the type of radiation concerned, gives the biologically effective dose in rem.

Relative biological effectiveness (RBE).	Defined in the note above. For X- and gamma radiation, the RBE is 1. For alpha particles and neutrons, the RBE is greater than 1.
Radiation effect	A response or change induced by exposure to ionizing radiation.
Clinical	A change of sufficient magnitude that it can be recognized by a trained observer or measured by laboratory tests.
Congenital	A change which affects the foetus and exists at the time of birth.
Genetic	A change in a reproductive cell which would alter the characteristics of an individual produced from the affected cell or which causes a mutation that is inheritable by subsequent generations.
Somatic	A change produced in any tissue which alters the normal body processes of the irradiated individual.
Radioactivity	The property or process whereby certain elements or nuclides spontaneously emit particles and/or gamma rays by the disintegration of the nuclei of their atoms.
Radionuclide	A radioactive nuclide.
Standard man	A hypothetical individual characterized by body organs of a size and functional capacity and with rates of ingestion, inhalation, elimination, etc. which constitute a useful biological model for man.
Strontium unit (SU)	One micromicrocurie of Sr^{90} per gram of calcium, usually in bone but now extended to items of food and milk.
Working limit	An exposure control established with due regard for: the probability of multiple radiation exposure in one task, the practical limitations of dose measurement, and the acknowledged degree of uncertainty in different exposure standards; such that the actual personnel exposure will not exceed the maximum permissible limit.

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